Surface N balances and reactive N loss from global intensive agricultural production systems for the period 1970-2030

Third International Nitrogen Conference, Nanjing, 12-16 October 2004

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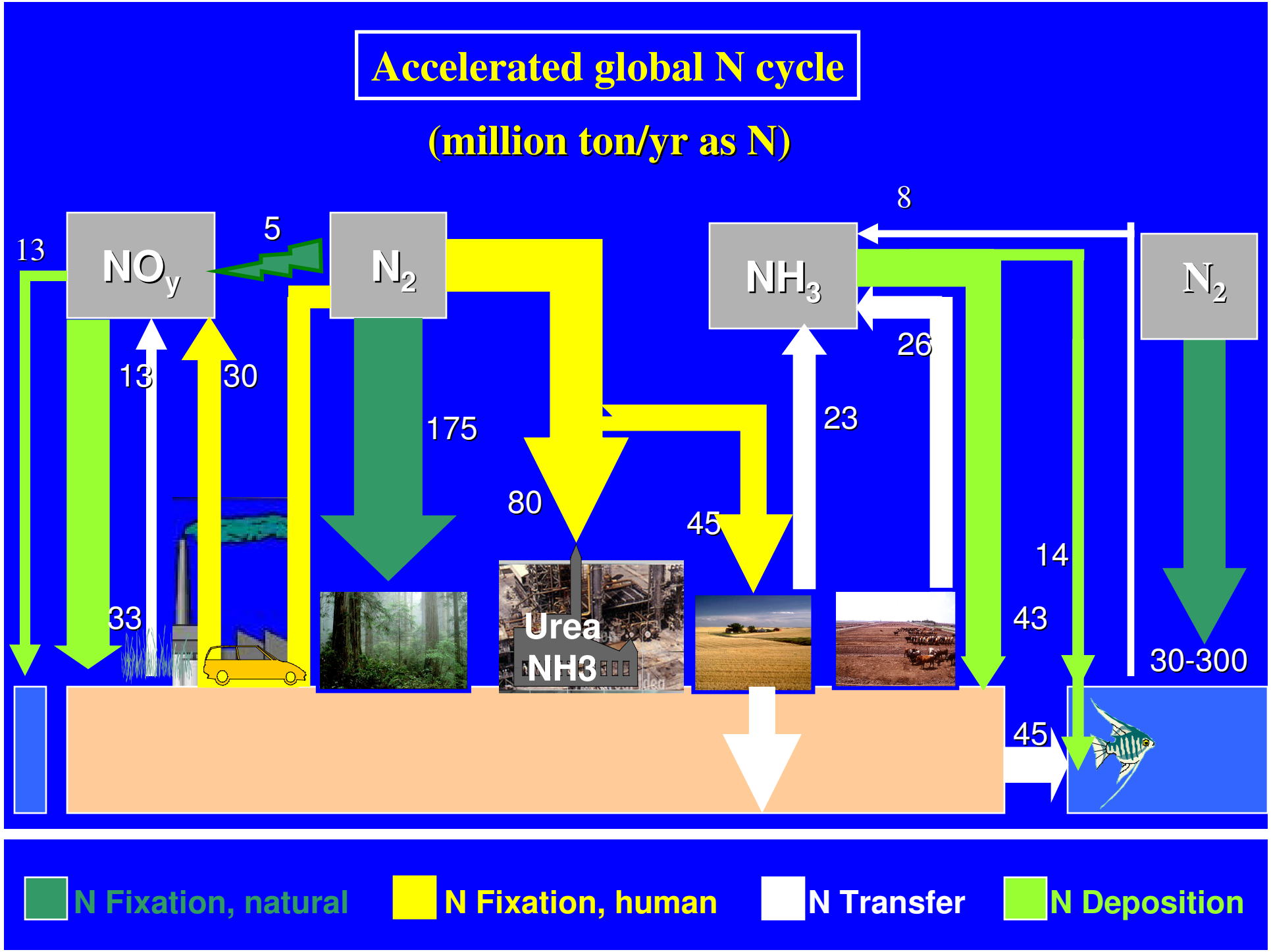
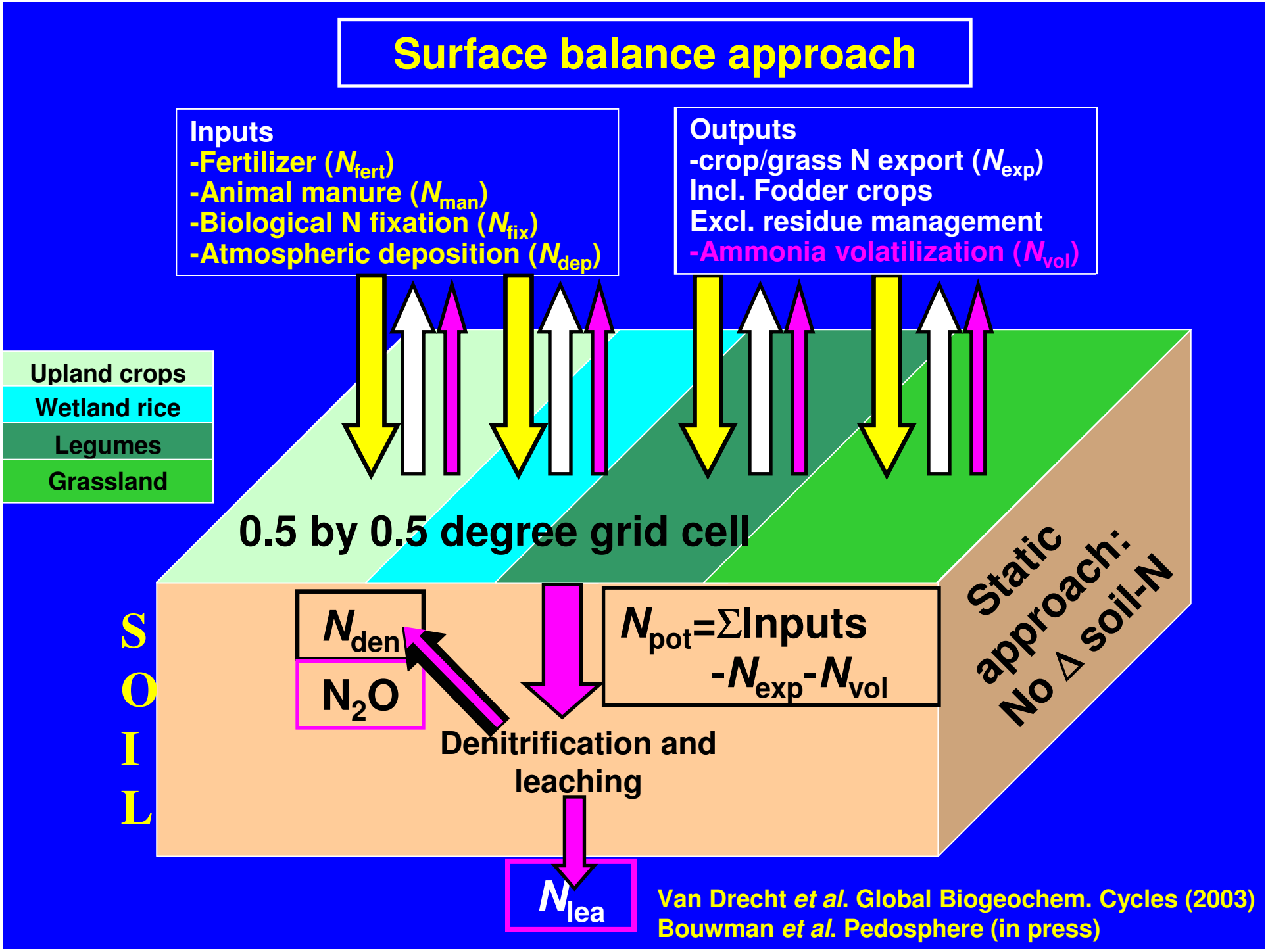
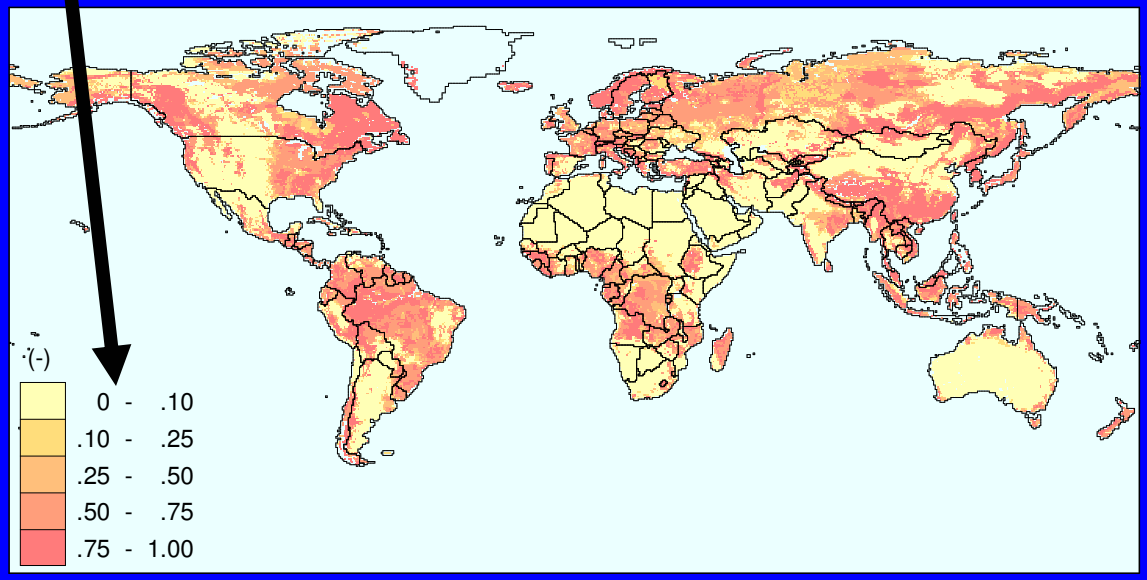

Accelerated global N cycle
(million ton/yr as N)
13
NOy
5
N2
8
NH3
N2
26
13
30
175
23
80
45
14
33
43
Urea
NH3
30-300
45
N Fixation, natural
N Fixation, human
N Transfer
N Deposition


Surface balance approach
Inputs
-Fertilizer (N_{fert})
-Animal manure (N_{man})
-Biological N fixation (N_{fix})
-Atmospheric deposition (N_{dep})
Outputs
-crop/grass N export (N_{exp})
Incl. Fodder crops
Excl. residue management
-Ammonia volatilization (N_{vol})
Upland crops
Wetland rice
Legumes
Grassland
0.5 by 0.5 degree grid cell
SOIL
N_{den}
N_2O
$N_{pot}=\Sigma$Inputs $-N_{exp}-N_{vol}$
Denitrification and leaching
N_{lea}
Static approach: No Δ soil-N
Van Drecht *et al.* Global Biogeochem. Cycles (2003)
Bouwman *et al.* Pedosphere (in press)

Denitrification and leaching

Upland crops

$$f_{lea} = \int (\text{climate}, \text{soil texture}, \text{drainage}, \text{carbon})$$



$$N_{den} = (1-f_{lea})\ N_{pot}$$
$$N_{lea} = f_{lea}\ N_{pot}$$

Wetland rice

$$f_{den} = 0.75 \text{ (based on measurements)}$$
$$f_{lea} = 0.25$$

Van Drecht *et al.* Global Biogeochemical Cycles (2003)

Integrated Model to Assess the Global Environment (IMAGE)

FAO World Agriculture Towards 2030 country data

0.5 by 0.5 degree resolution

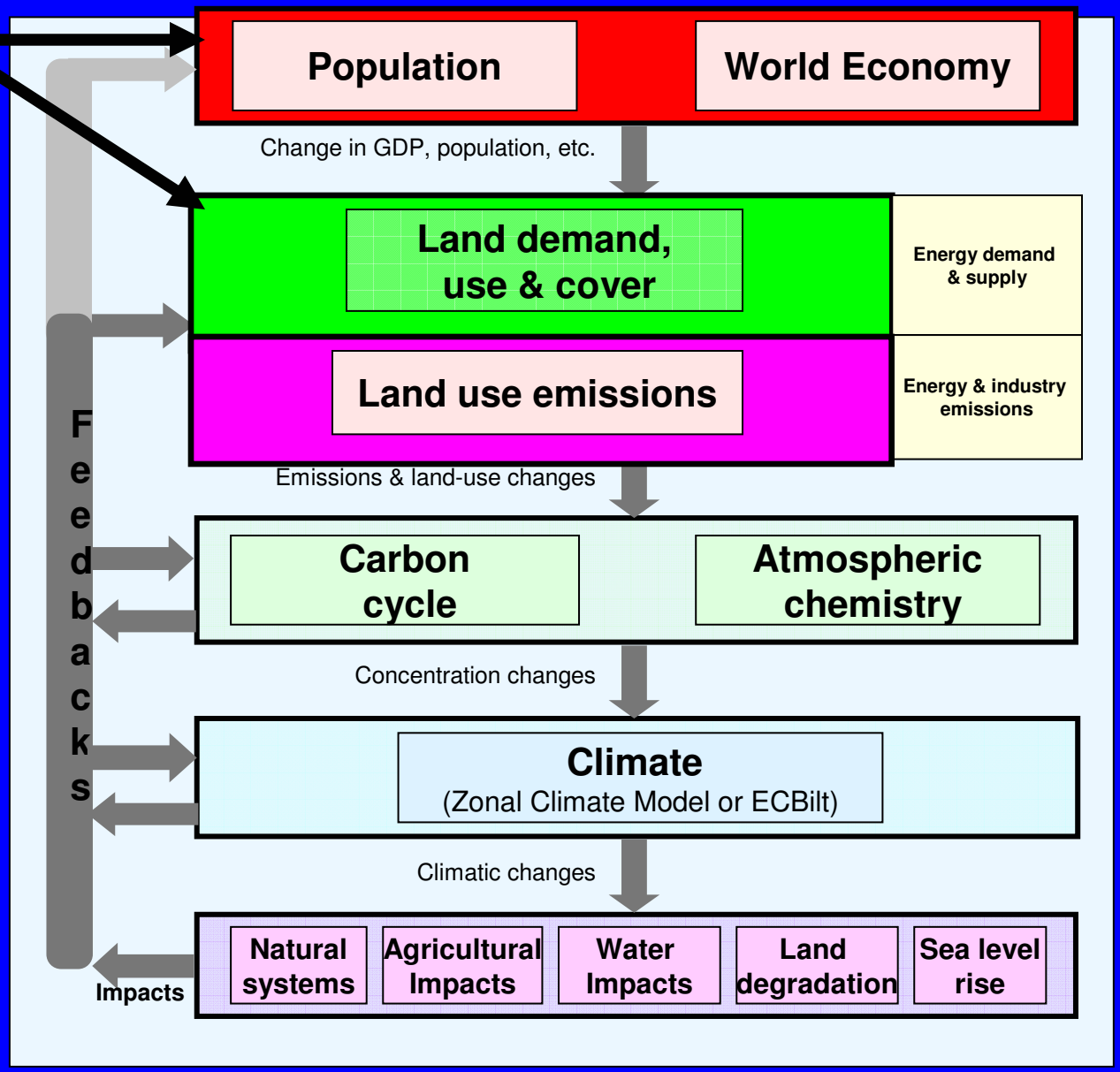


Image-team (2001)

Integrated Model to Assess the Global Environment (IMAGE)

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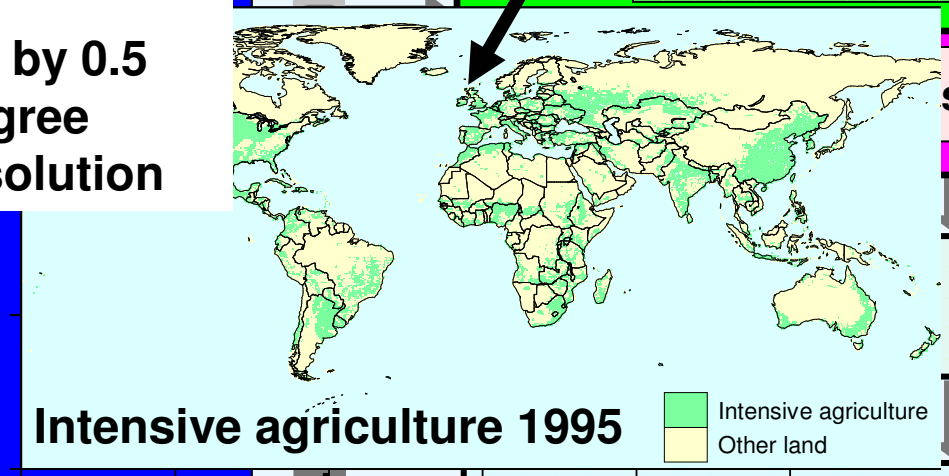

Population

World Economy

Change in GDP, population, etc.

Land demand, use & cover

Energy demand & supply

sions

Energy & industry emissions

Atmospheric chemistry

k

s

Climate
(Zonal Climate Model or ECBilt)

Climatic changes

Impacts

Natural systems

Agricultural Impacts

Water Impacts

Land degradation

Sea level rise

Image-team (2001)

Integrated Model to Assess the Global Environment (IMAGE)

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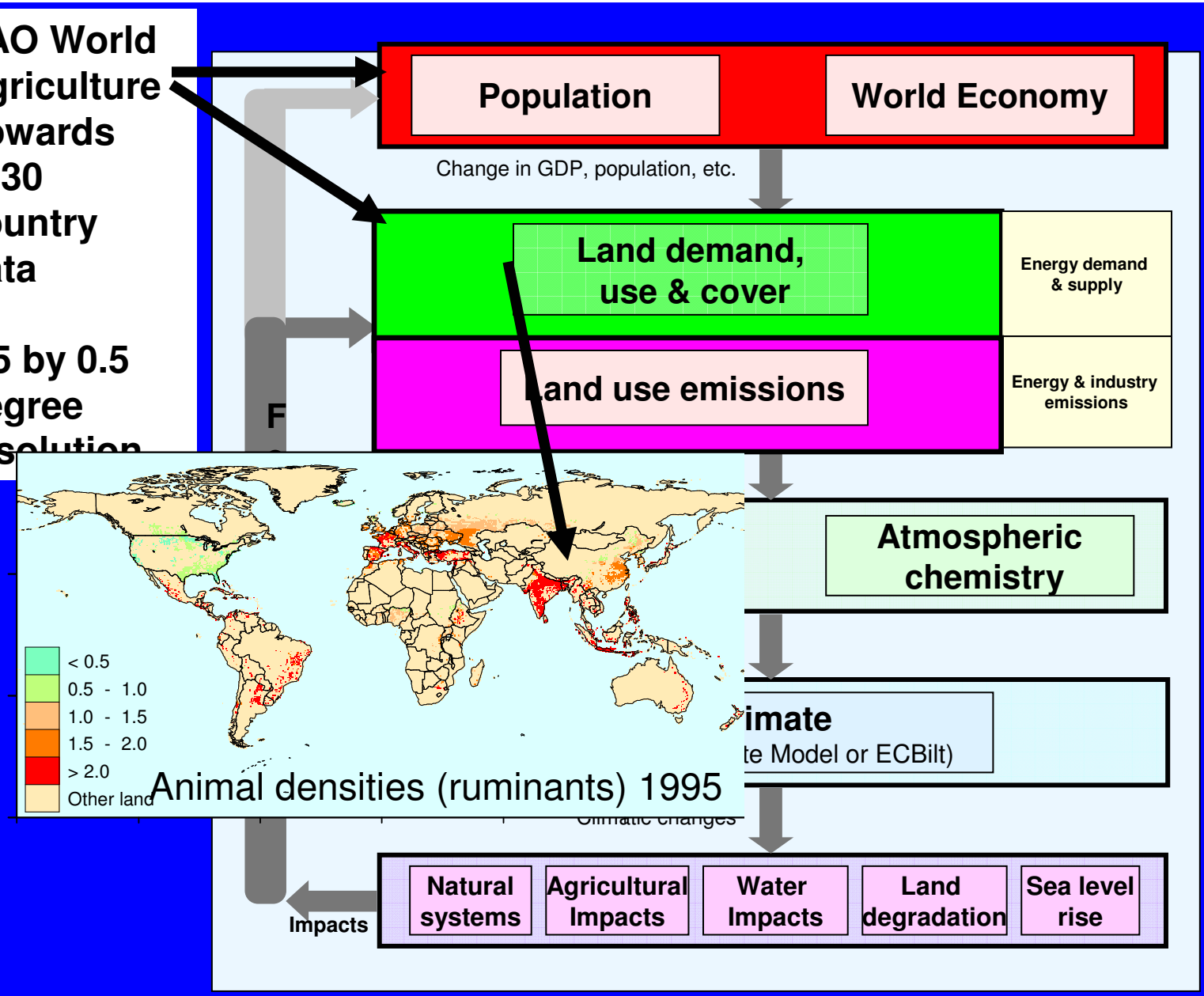

Image-team (2001)

Integrated Model to Assess the Global Environment (IMAGE)

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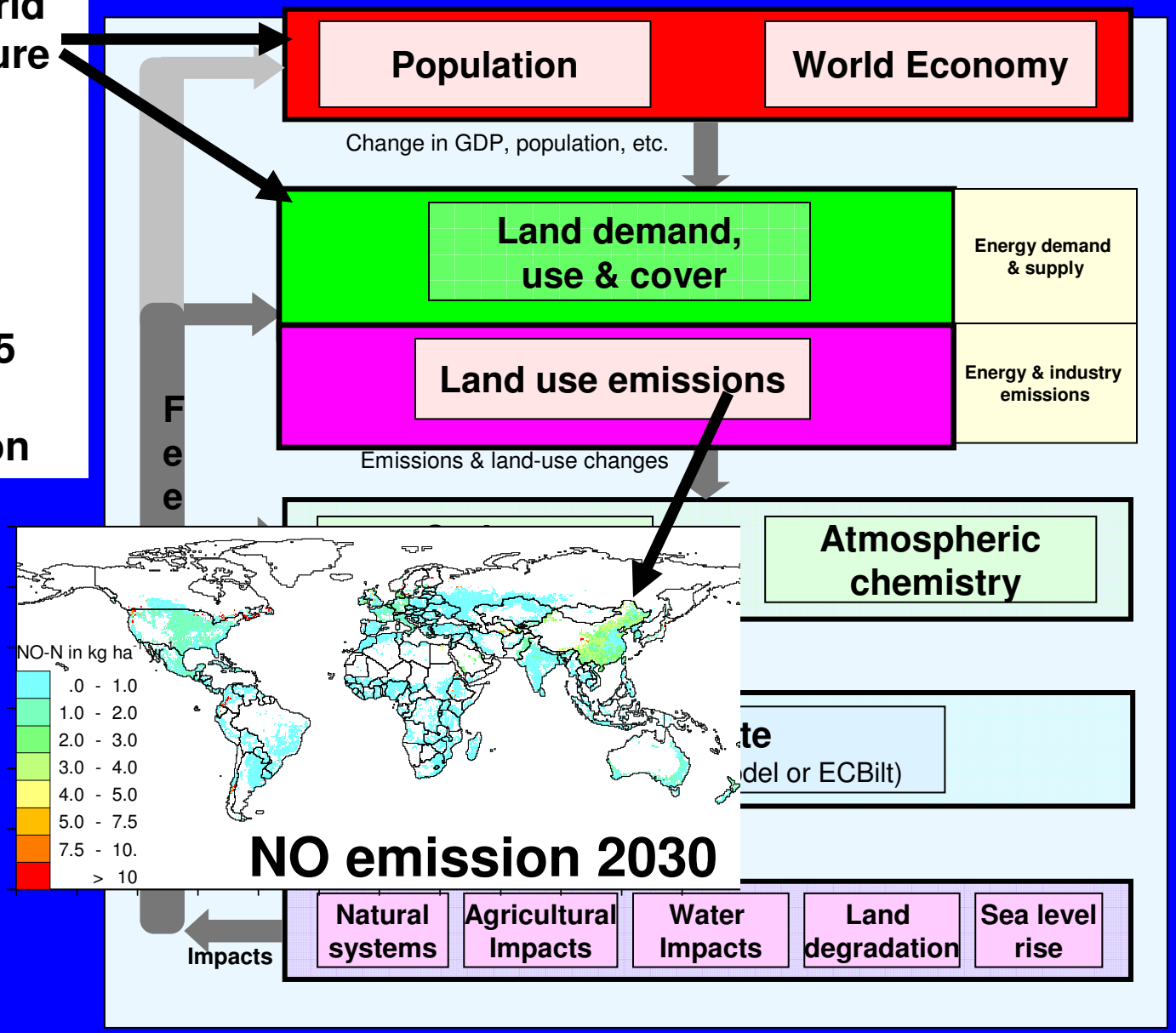

Image-team (2001)

Integrated Model to Assess the Global Environment (IMAGE)

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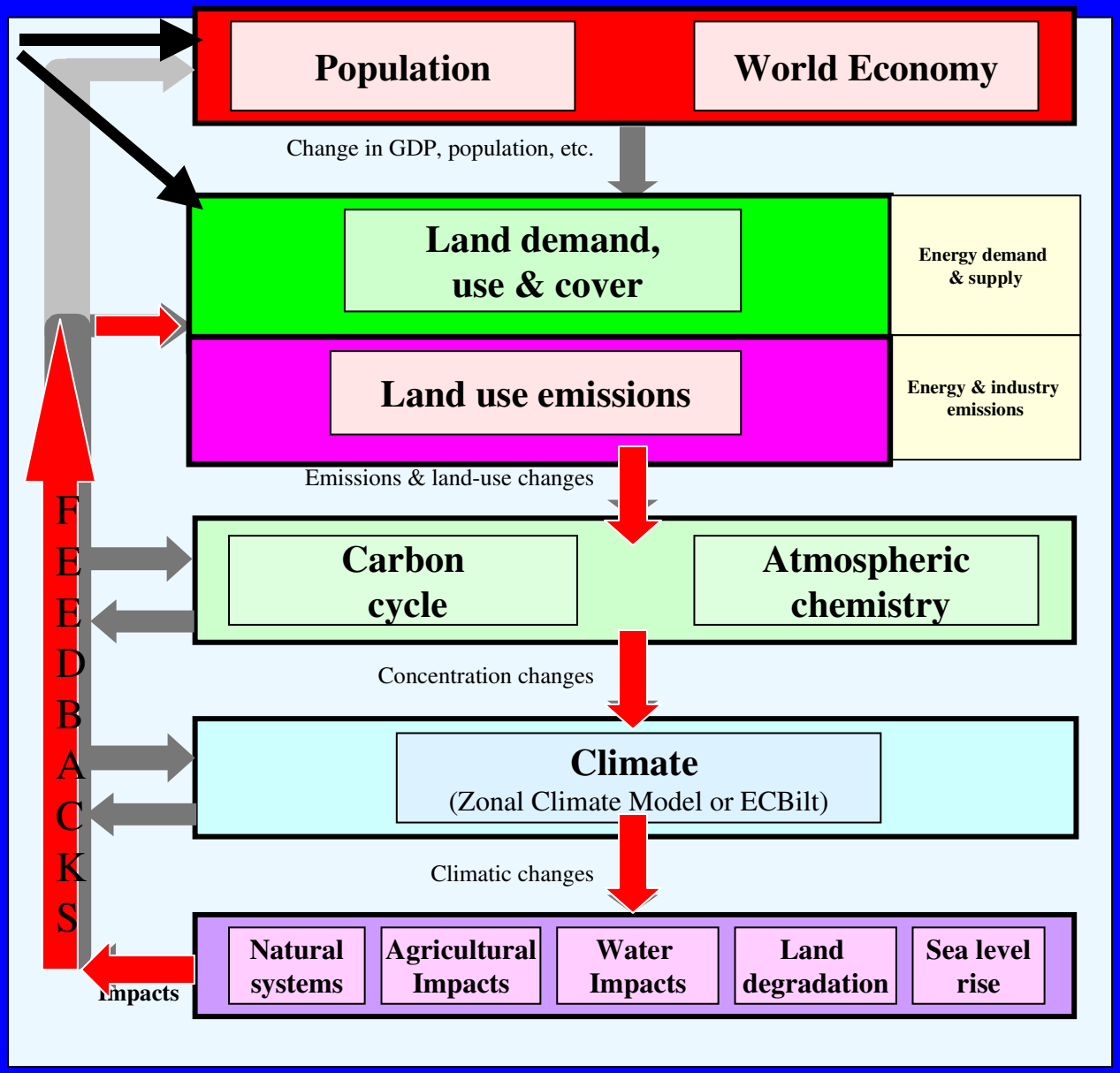


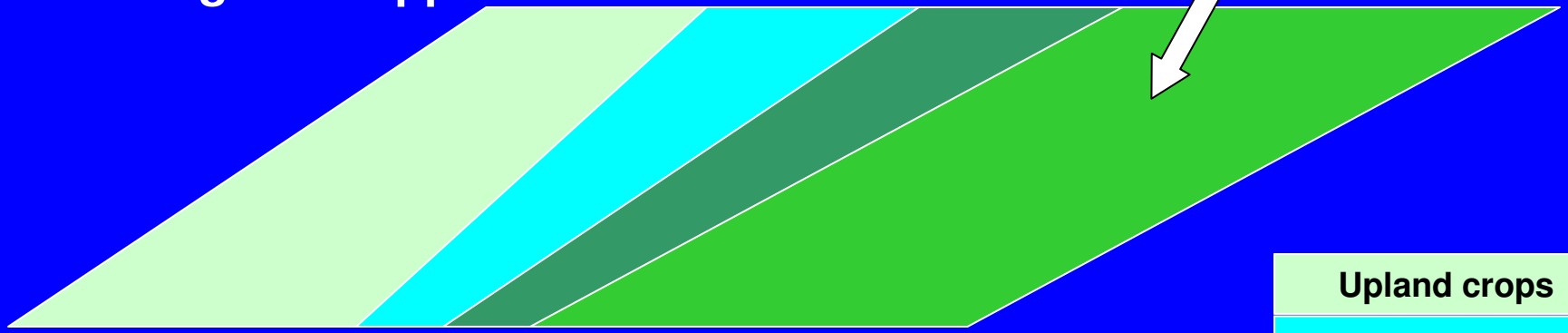
Image-team (2001)

IMAGE Production systems

Mixed systems

Close to urban areas, rivers
Fertilizers, different feedstuffs
Manure storage and application

0.5 by 0.5 degree grid cell



Upland crops
Wetland rice
Legumes
Grassland

Pastoral systems and marginal grassland

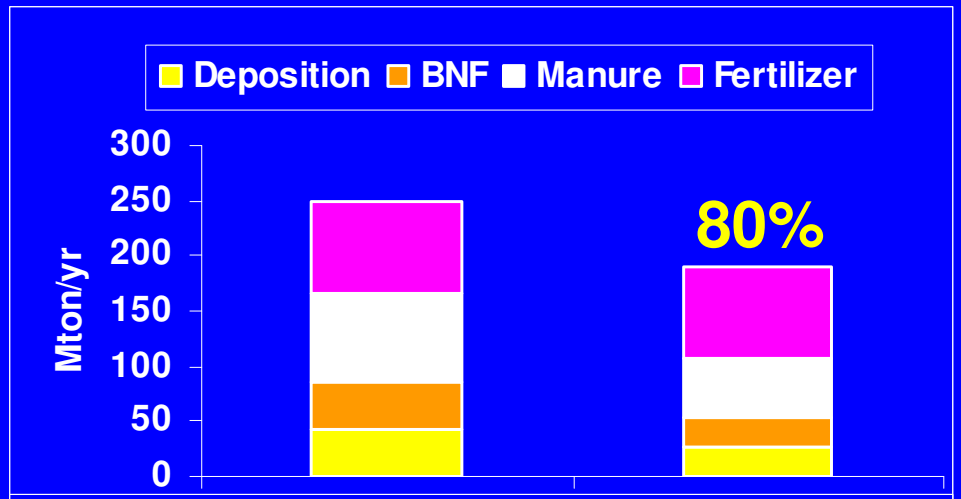
More remote from urban areas
Grazing mainly
Limited manure storage and application

Excluded for better comparison between countries

Bouwman *et al.* Pedosphere (in press)

IMAGE production systems

Inputs



Outputs

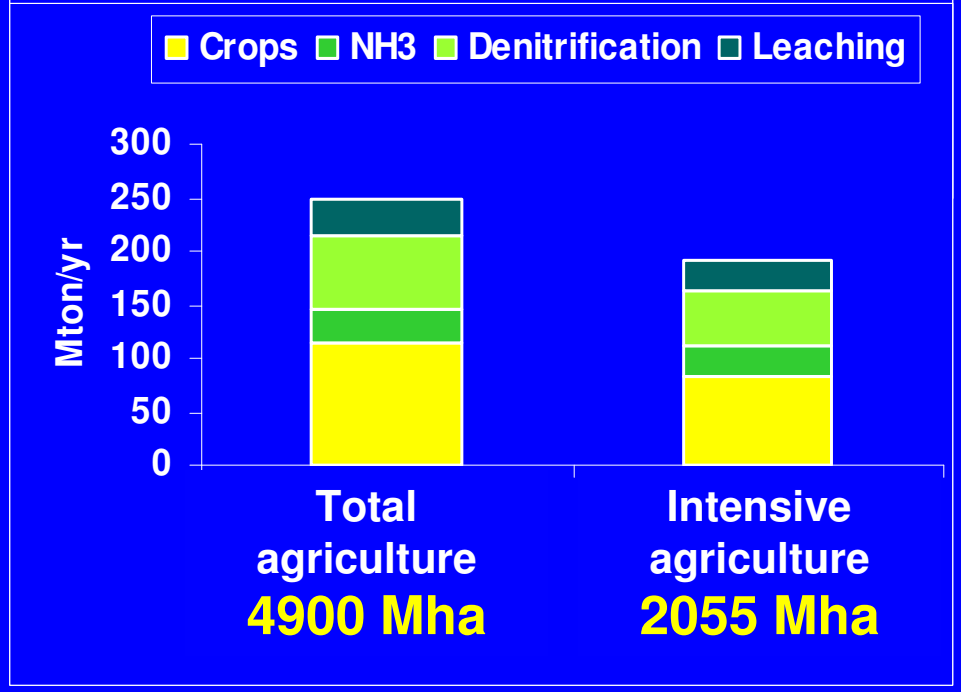
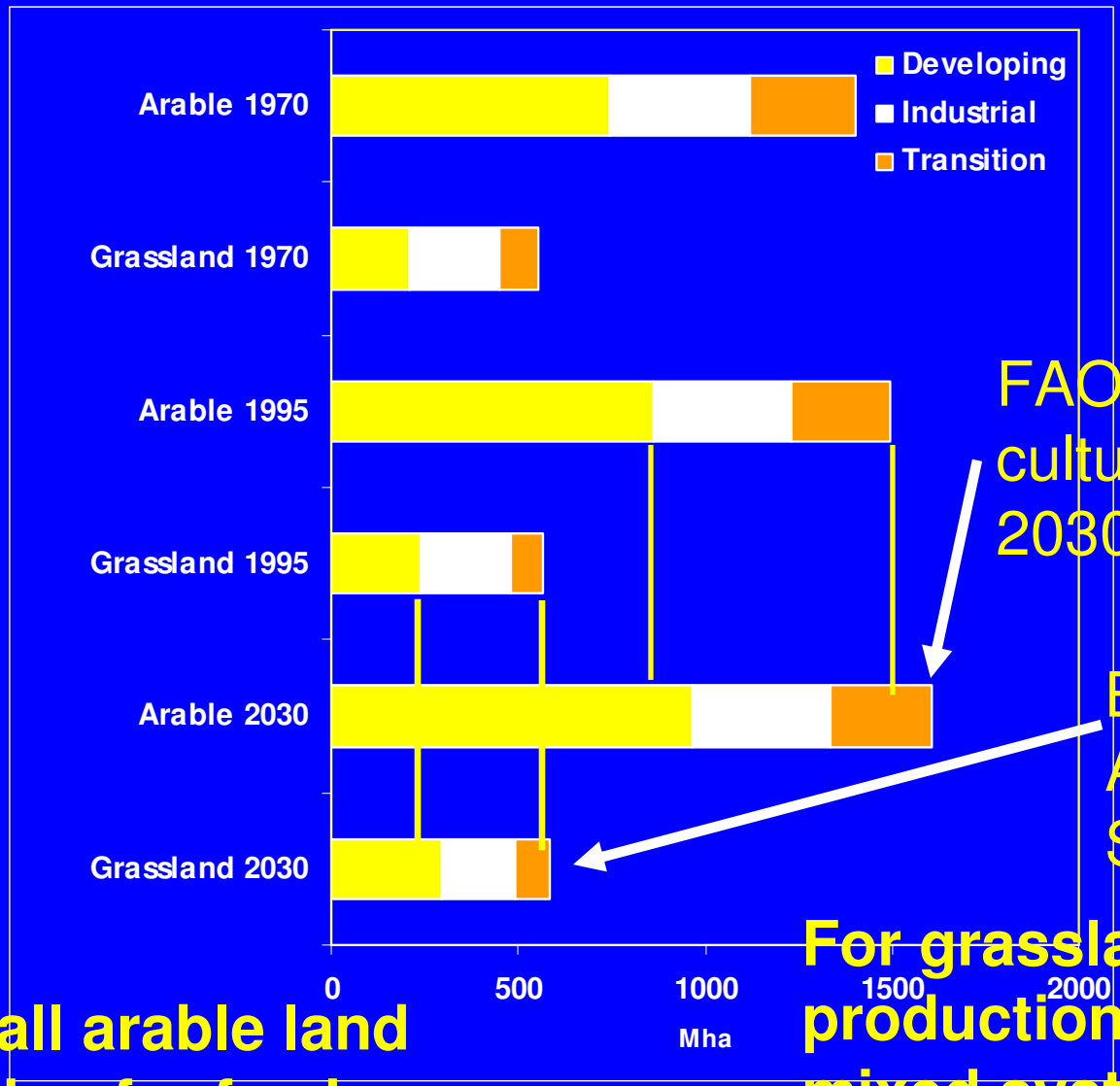


IMAGE land use projection



FAO World Agriculture: Towards 2030 projection

Bouwman *et al.* Agricultural Systems (2004)

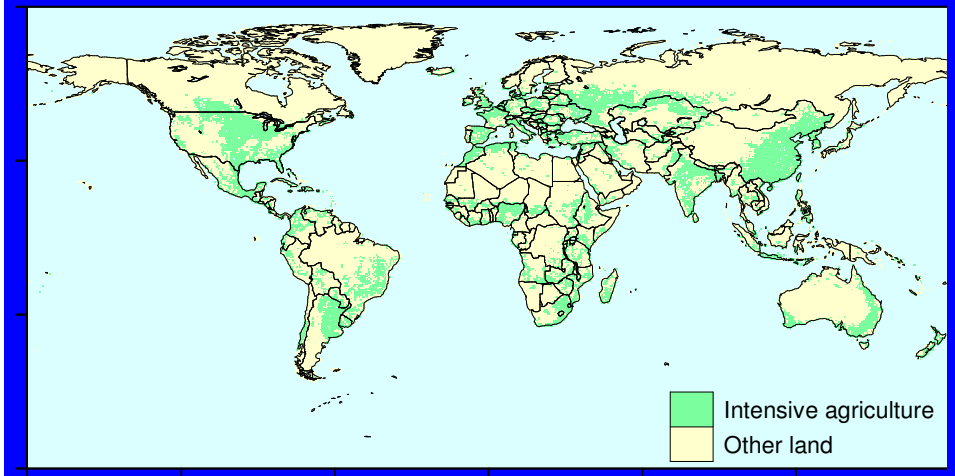
Nearly all arable land expansion for feed production

For grasslands most production increase in mixed systems

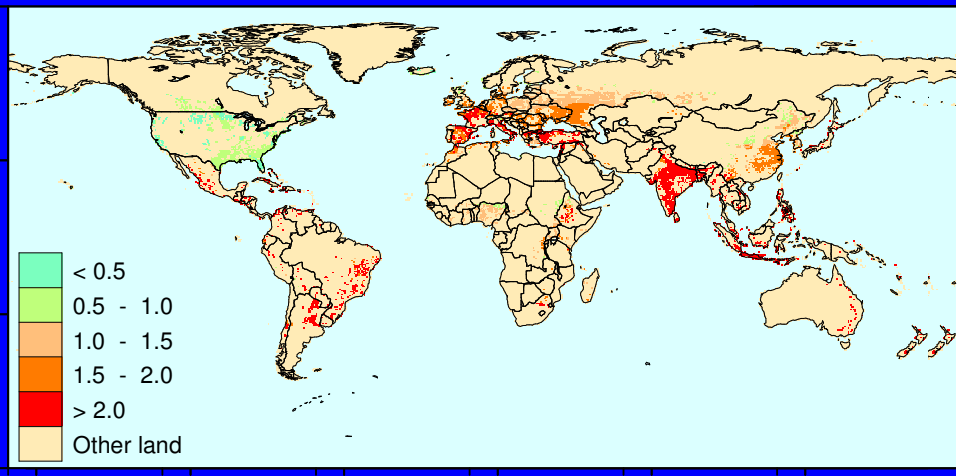
Bouwman *et al.* Agricultural Systems (2004)

IMAGE land use projection

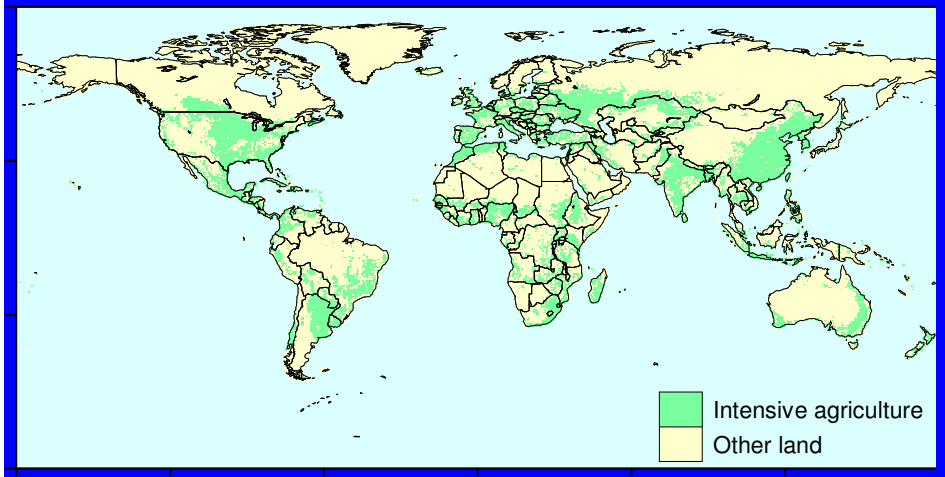
Intensive agriculture 1995



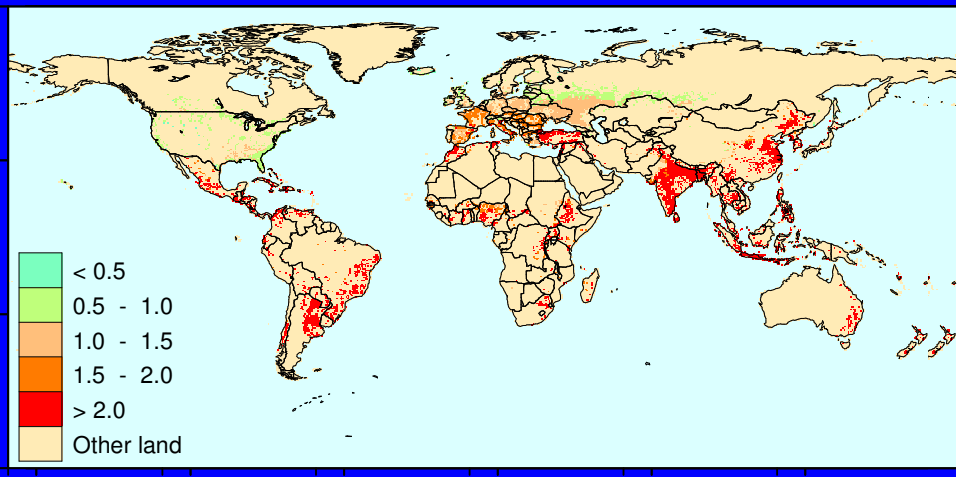
Animal densities (ruminants) 1995



Intensive agriculture 2030



Animal densities (ruminants) 2030



Bouwman *et al.* Agricultural Systems (2004)

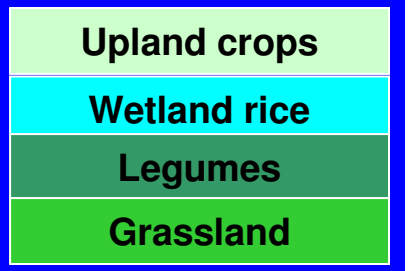
Surface nutrient balance

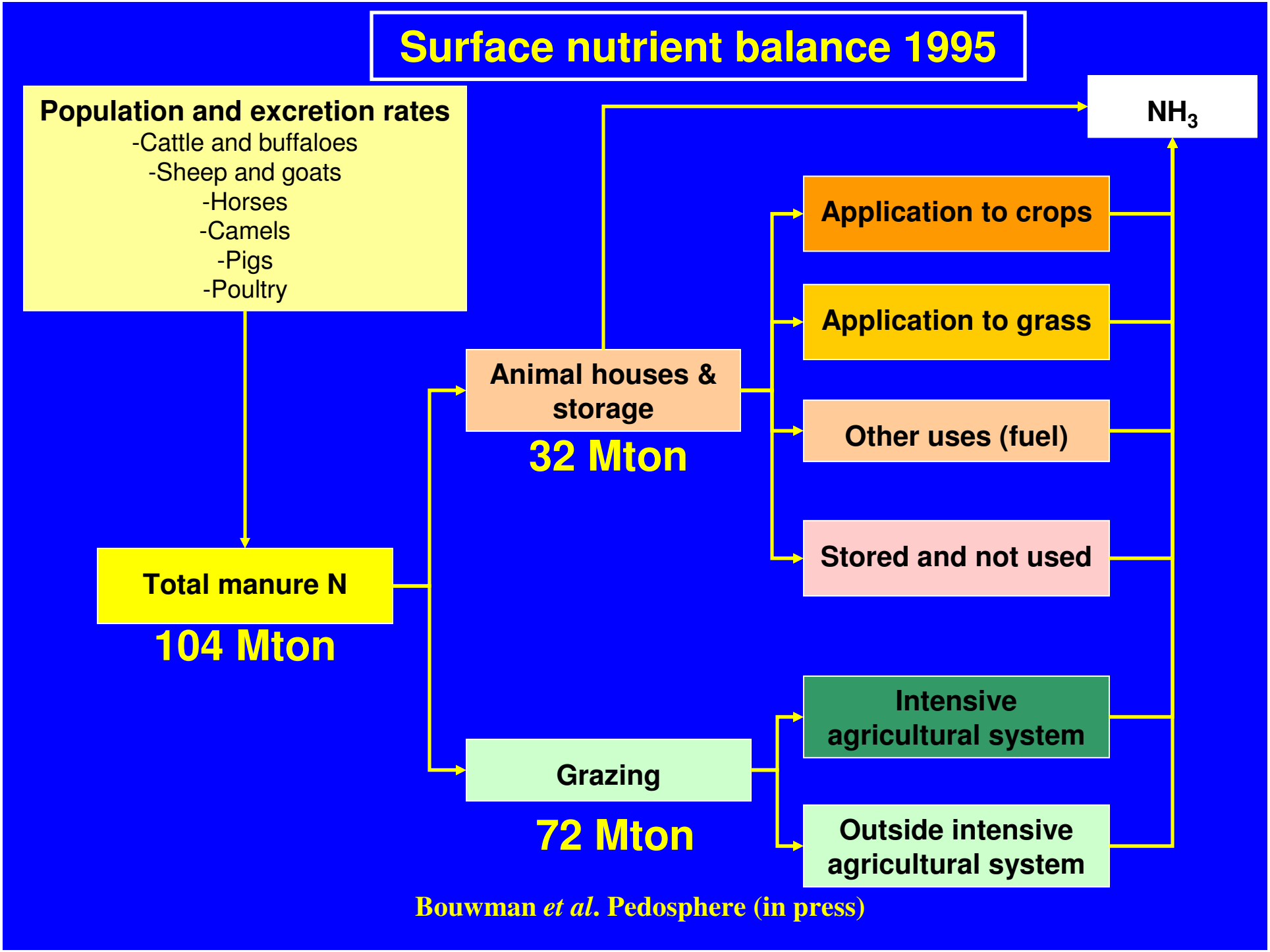
FAO World Agriculture Towards 2030:

N and P fertilizer use for 1970, 1995 and 2030

	1970	1995	2030
		N fertilizer use (Mton yr^{-1} as N)	
Developing countries	9	50	73
Industrialized countries	15	24	30
Transition countries	7	5	6
World	32	79	109
		P fertilizer use (Mton yr^{-1} as P_2O_5)	
Developing countries	4	19	37
Industrialized countries	12	10	14
Transition countries	5	1	2
World	21	31	52

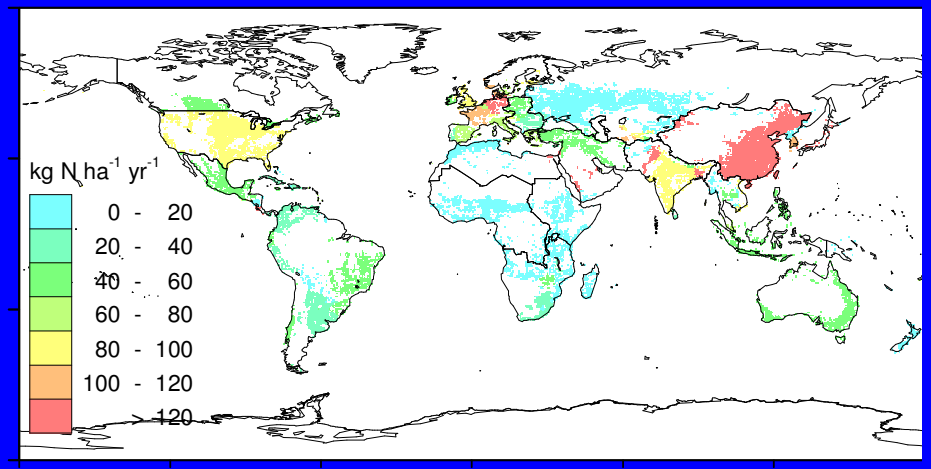
For allocation:
Fertilizer use by crop
(FAO/IFA/IFDC, 2003)



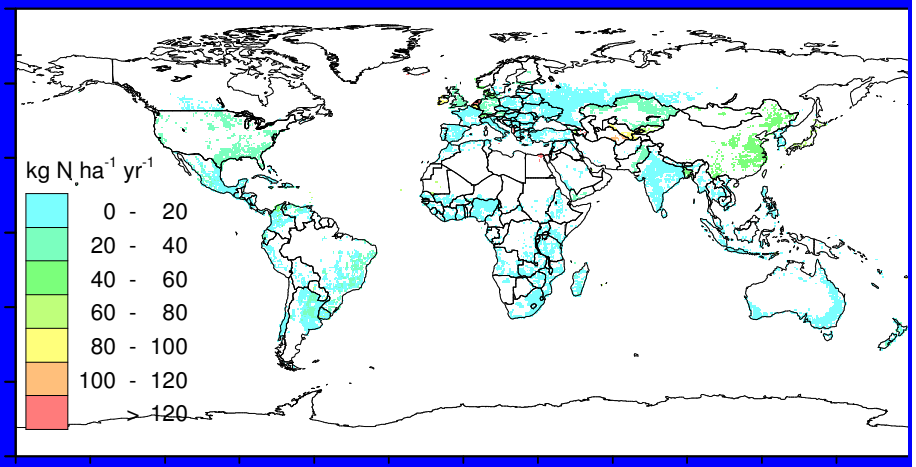

Surface nutrient balance 1995
Population and excretion rates
-Cattle and buffaloes
-Sheep and goats
-Horses
-Camels
-Pigs
-Poultry
NH3
Application to crops
Application to grass
Other uses (fuel)
Stored and not used
Animal houses & storage
32 Mton
Total manure N
104 Mton
Grazing
72 Mton
Intensive agricultural system
Outside intensive agricultural system
Bouwman et al. Pedosphere (in press)

N balance upland crops 1995

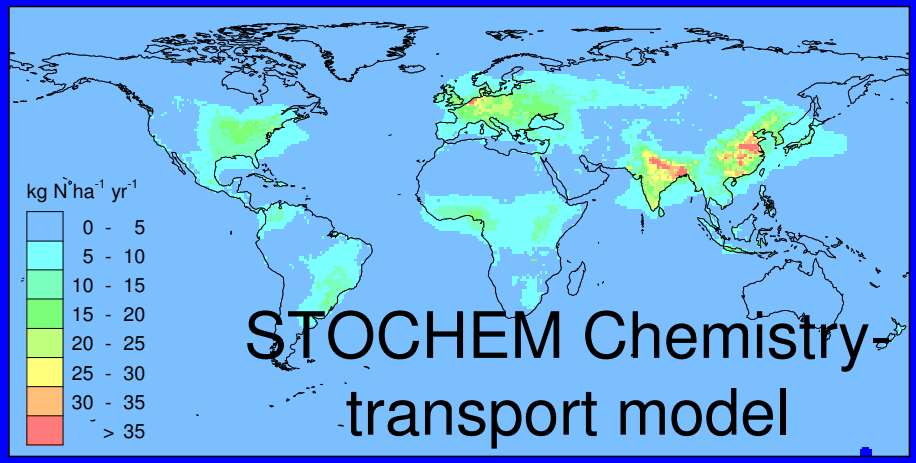
N fertilizer



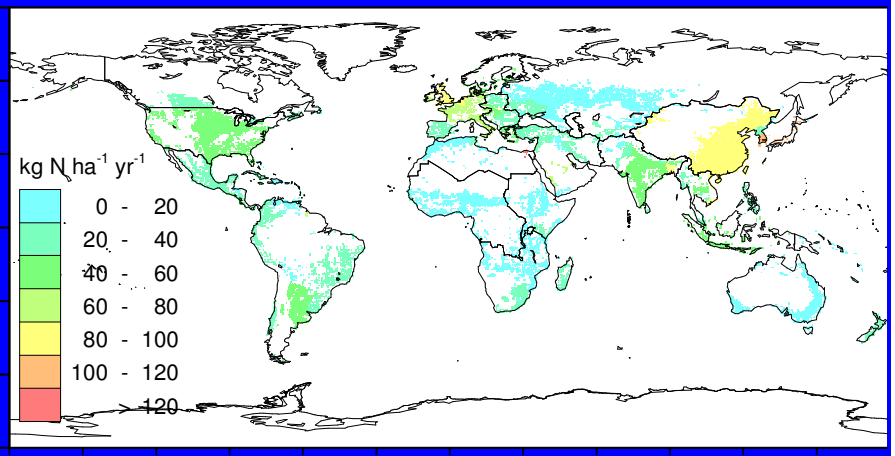
N manure



N deposition

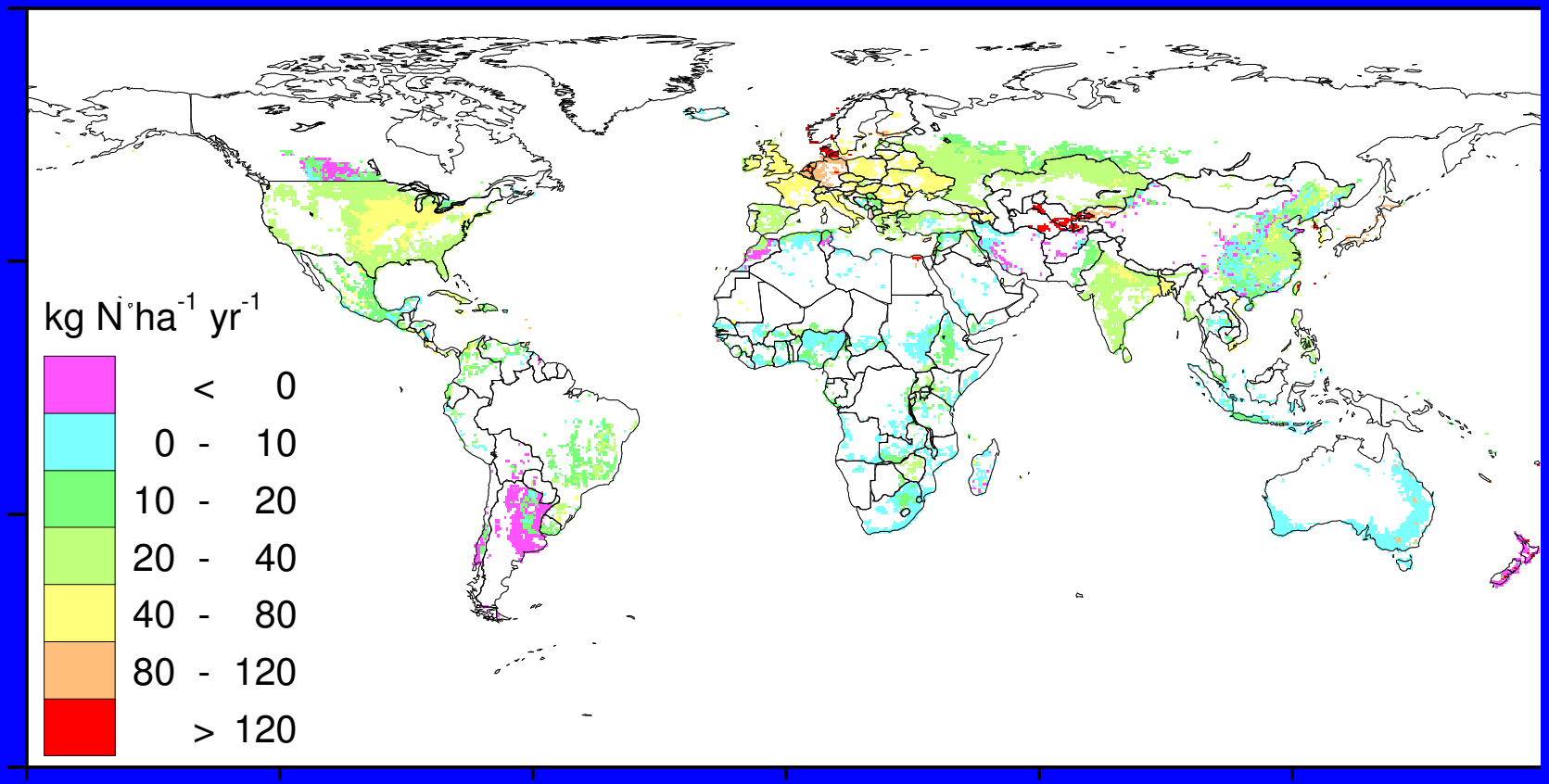


N uptake



N balance intensive systems 1970

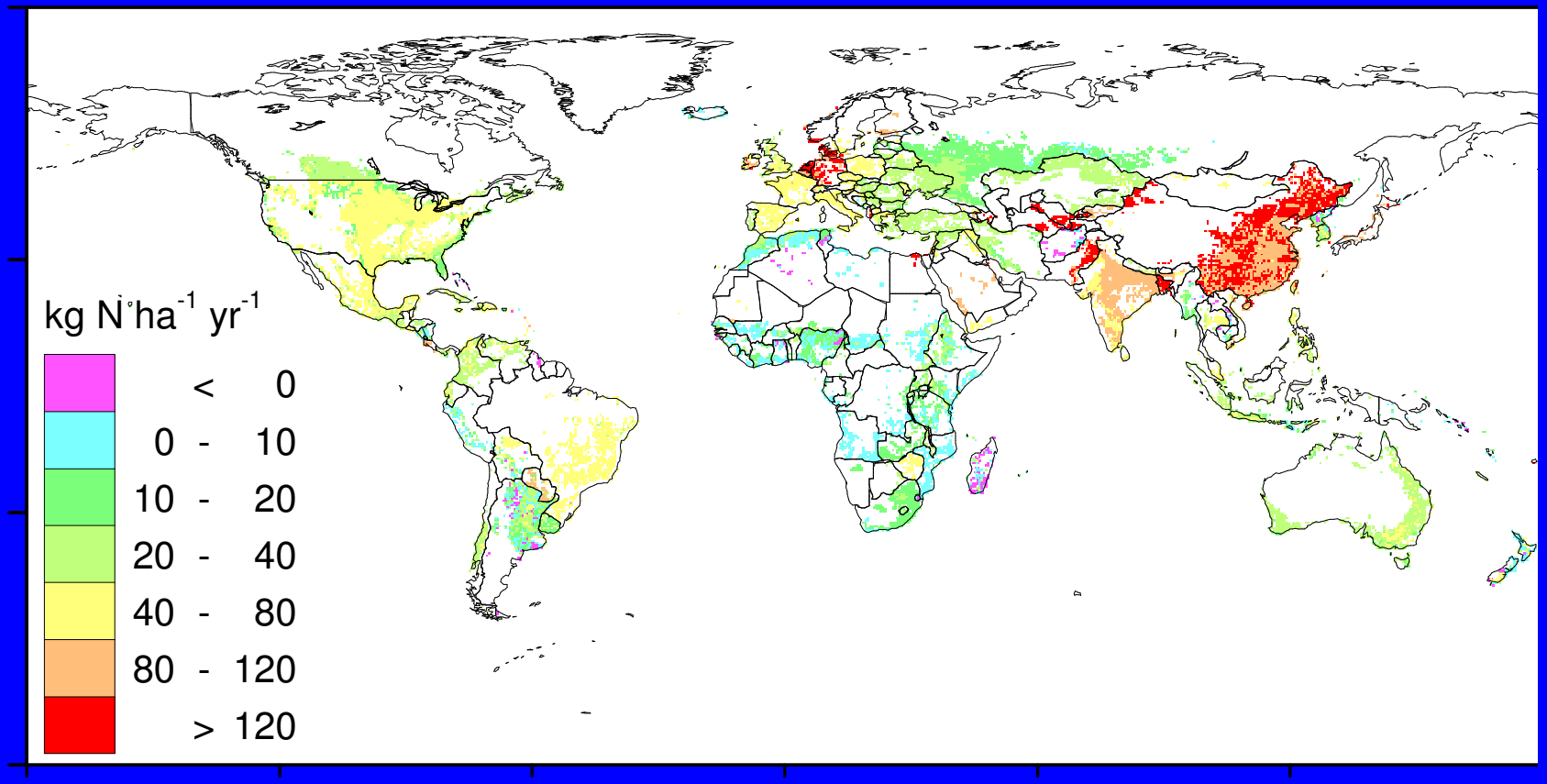
1970



N surplus = total N inputs - crop/grass export

N balance intensive systems 1995

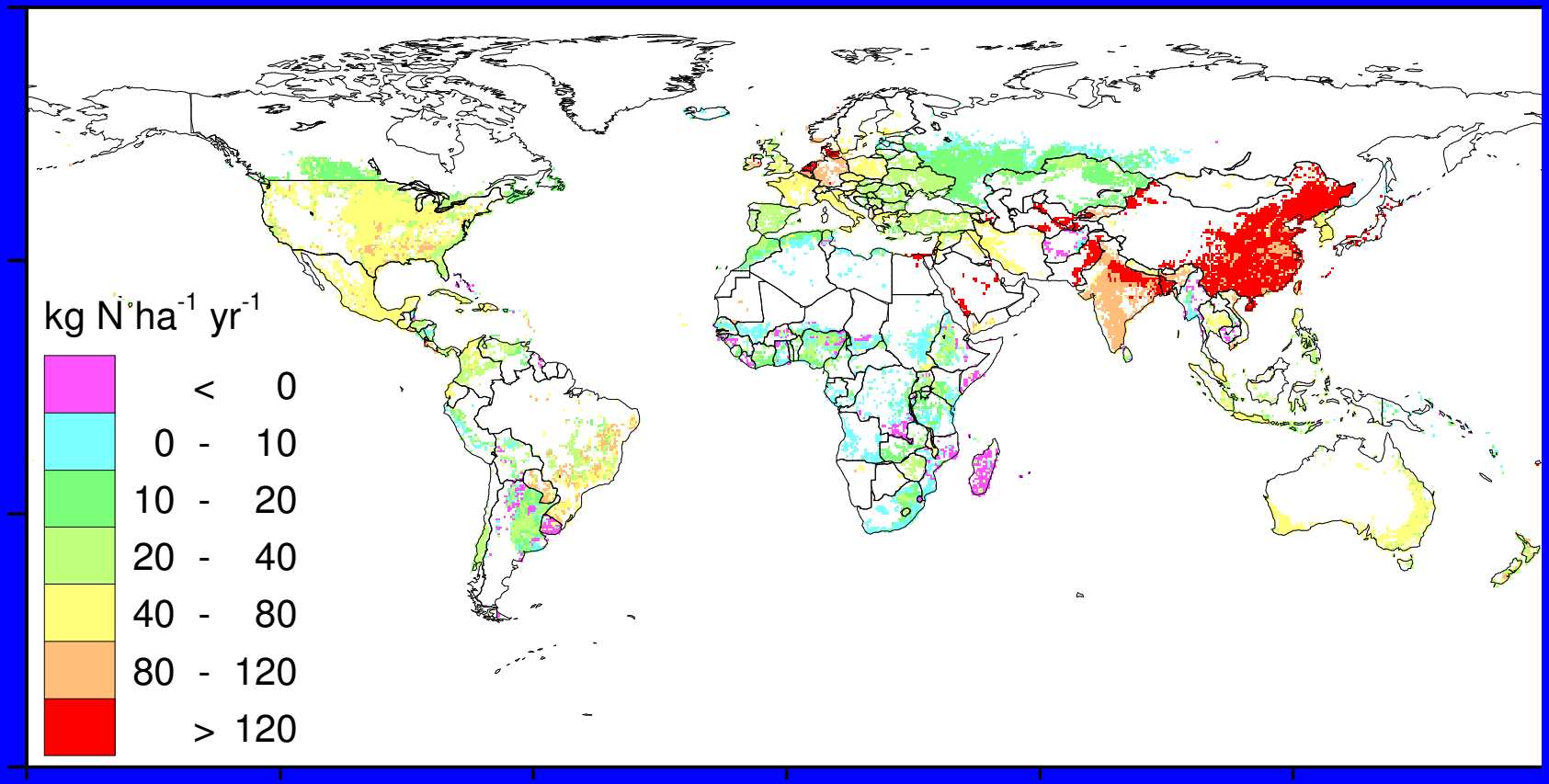
1995



N surplus = total N inputs - crop/grass export

N balance intensive systems 2030

2030



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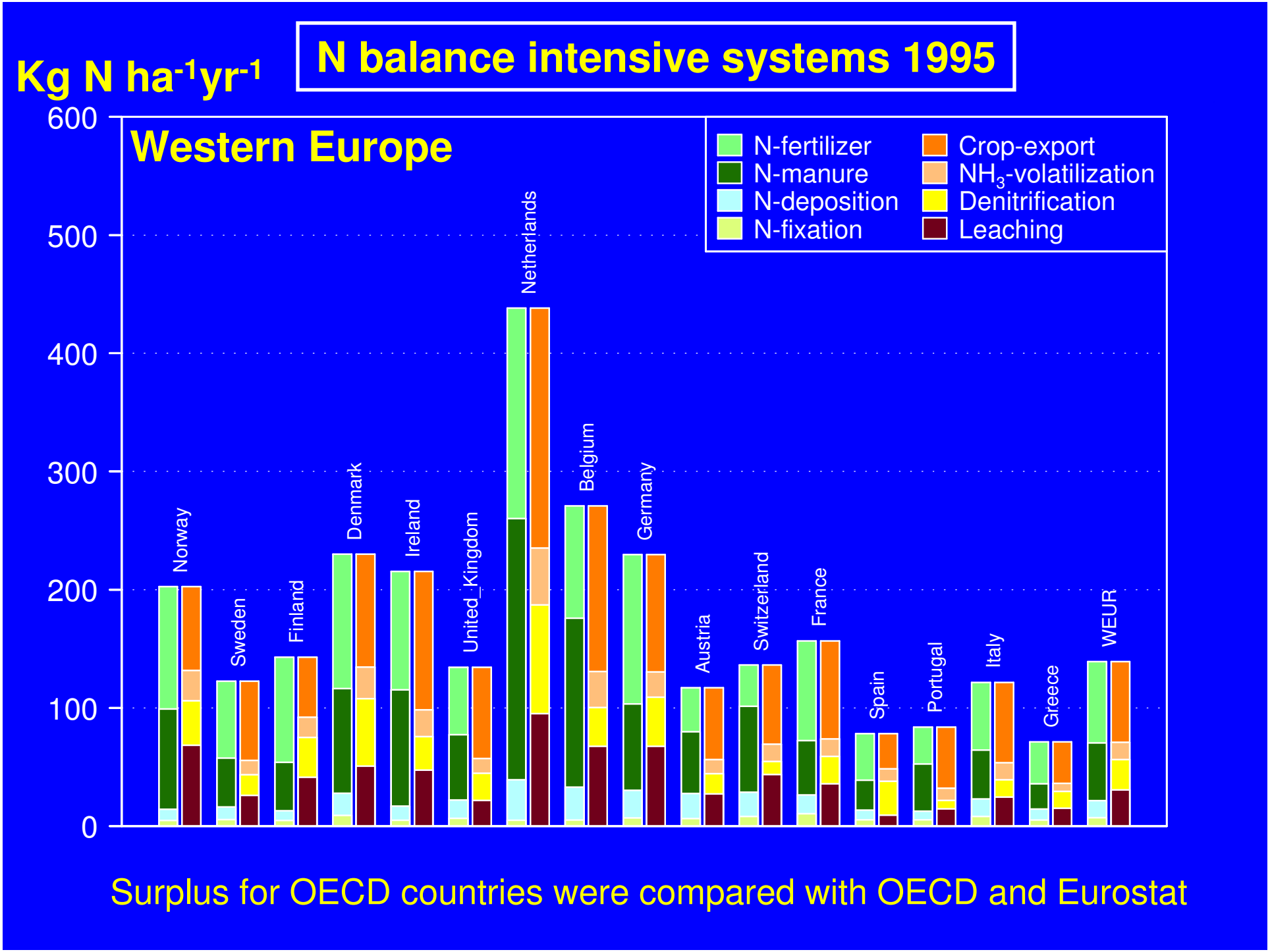
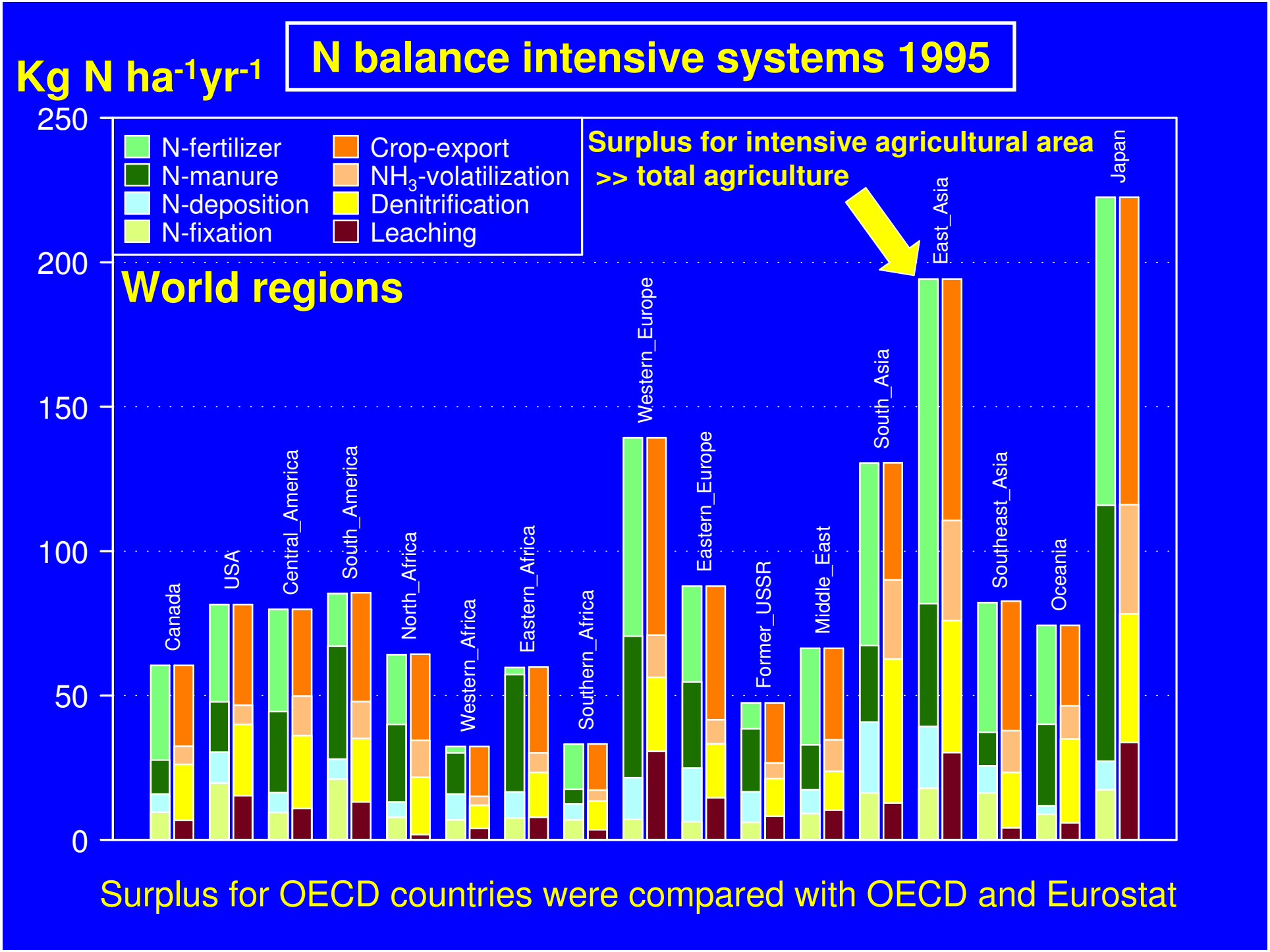


Surplus for OECD countries were compared with OECD and Eurostat


N balance intensive systems 1995
Kg N ha-1yr-1
250
200
150
100
50
0
N-fertilizer
N-manure
N-deposition
N-fixation
Crop-export
NH3-volatilization
Denitrification
Leaching
Surplus for intensive agricultural area
>> total agriculture
World regions
Canada
USA
Central_America
South_America
North_Africa
Western_Africa
Eastern_Africa
Southern_Africa
Western_Europe
Eastern_Europe
Former_USSR
Middle_East
South_Asia
East_Asia
Southeast_Asia
Oceania
Japan
Surplus for OECD countries were compared with OECD and Eurostat

N balance 1995

China cropland

	Zhu & Chen (2002)-1998	Bouwman *et al.* (in press)-1995
	(Mton yr^{-1})	
INPUTS		
Fertilizer	25	24
Manure	5	4
Biological fixation	3	3
Atm. deposition	2	3
Total	**36**	**33**
OUTPUTS		
Harvest	15	13
Gaseous loss	12	15
Leaching + runoff	2	5
Unaccounted for	6	-
Total	**36**	**33**

Accumulation and retention in subsoil and groundwater

Fertilizer use efficiency
Overall system N recovery

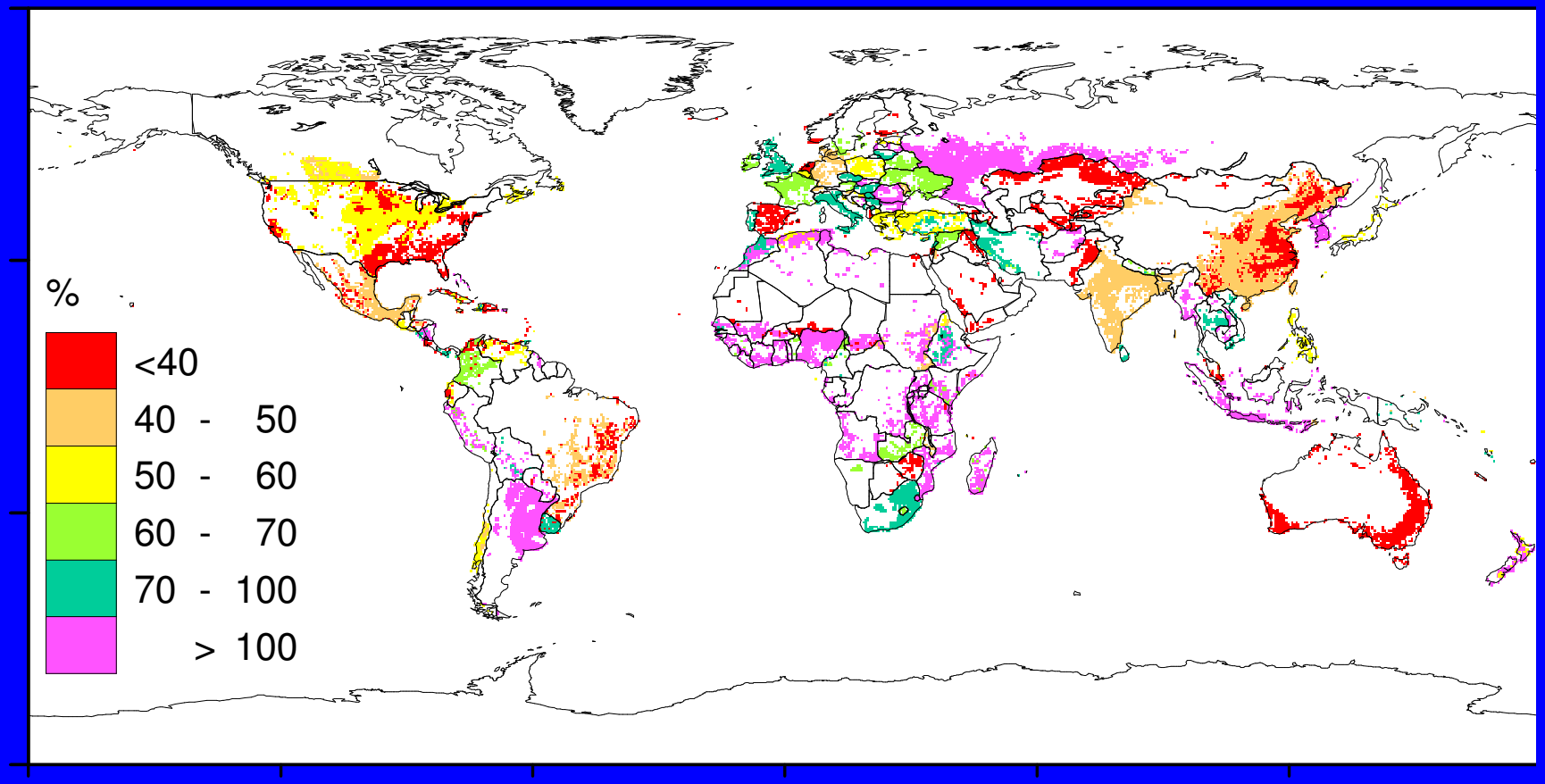
$$\text{FUE} = \frac{\text{crop N export}}{\text{N fertilizer} + \text{manure N input}}$$

For wetland rice and upland crops, excluding legumes

$$\text{Overall system N recovery} = \frac{\text{crops} + \text{grass}}{\sum \text{N inputs}}$$

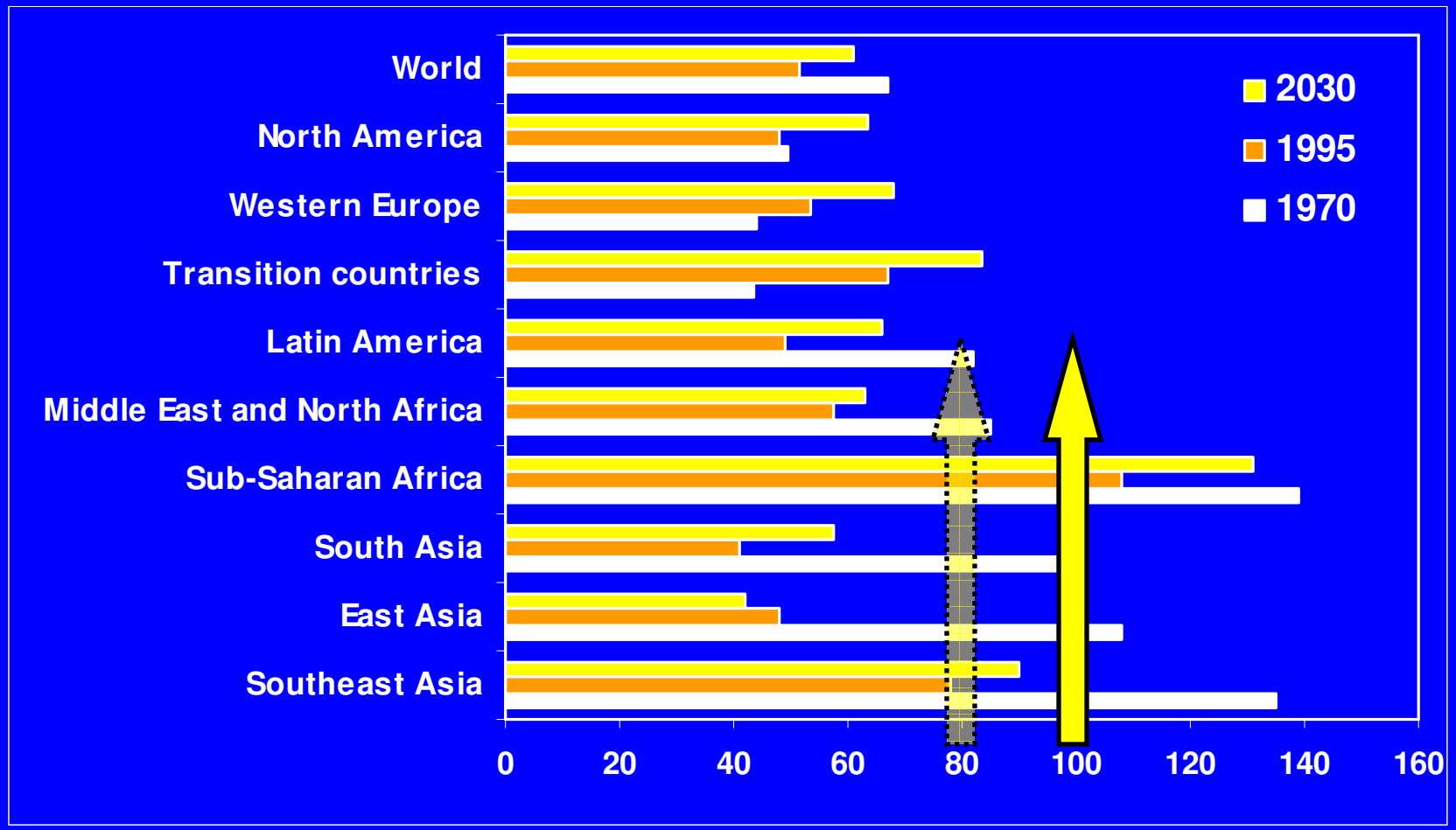
Fertilizer, manure, biological N fixation, deposition

Fertilizer use efficiency upland crops 1995



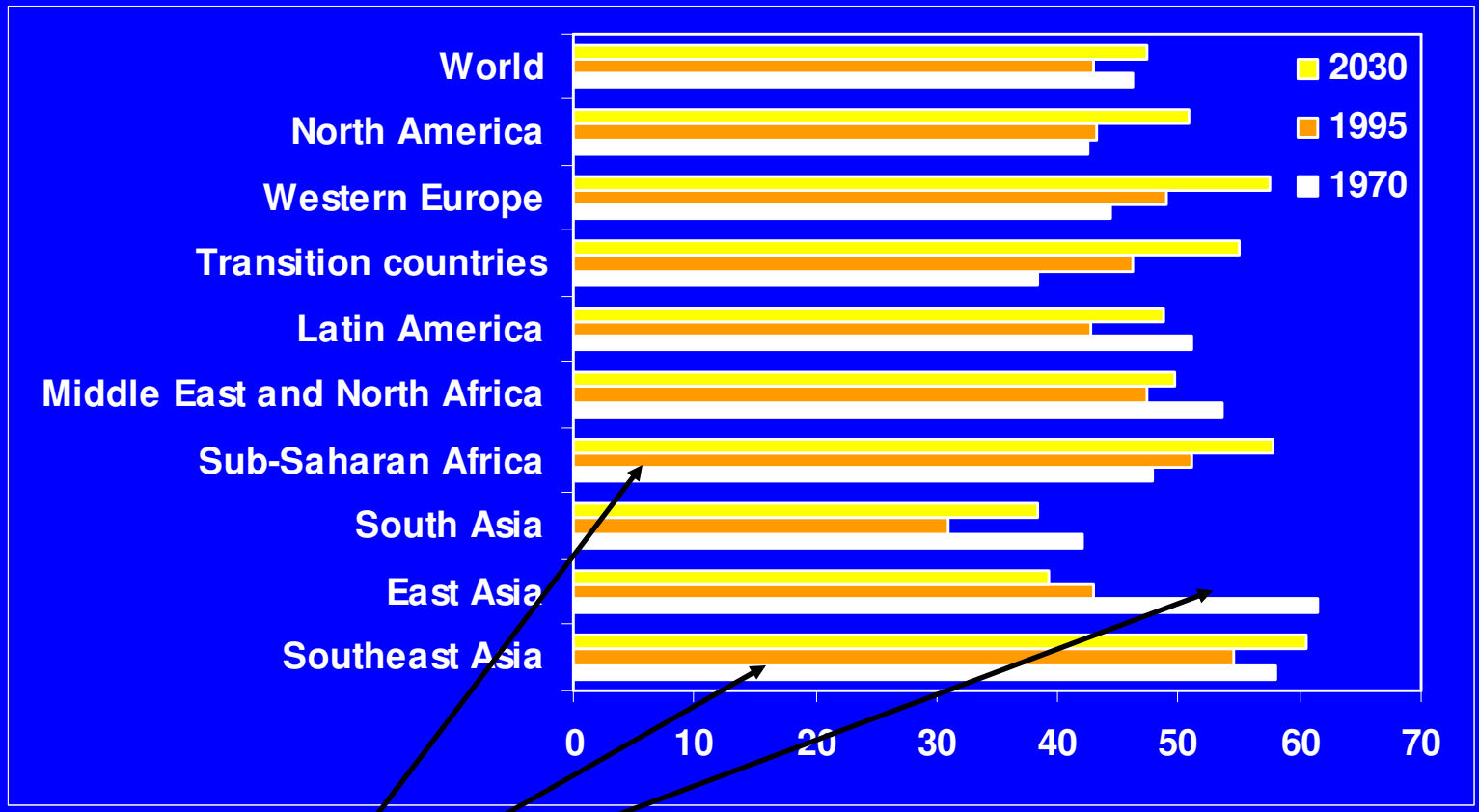
Current N deficit systems may change into systems with surpluses

Fertilizer use efficiency (%) wetland rice + upland crops



Soil N depletion

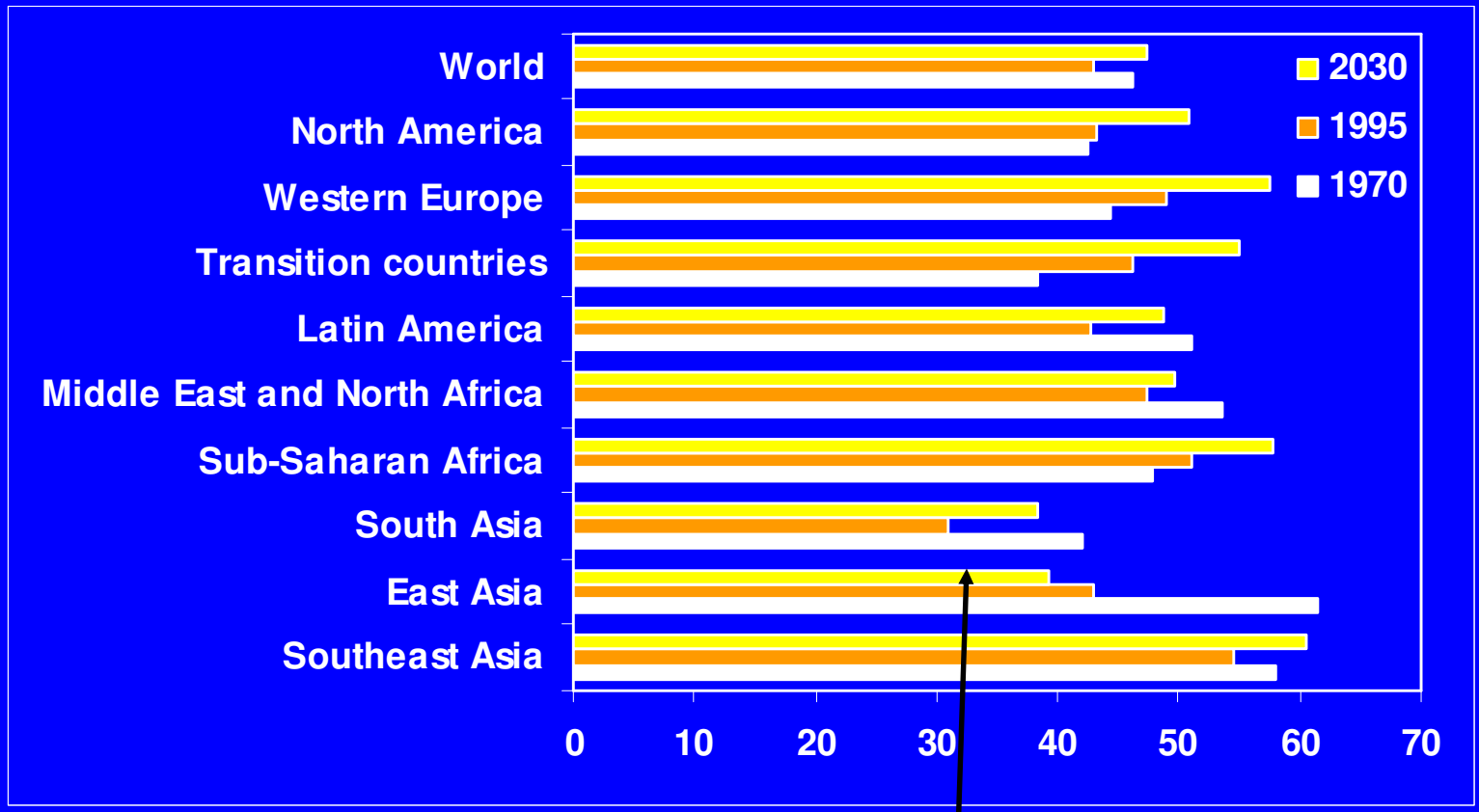
Intensive systems:
Overall system N recovery in % of inputs



DIFFERENCES HAVE MANY CAUSES:

- Soil N depletion
- Climate/soils
- Productivity
- Management
- Over-fertilization
- Wetland rice
- Legumes
- Underestimation of N in harvest

Intensive systems:
Overall system N recovery in % of inputs



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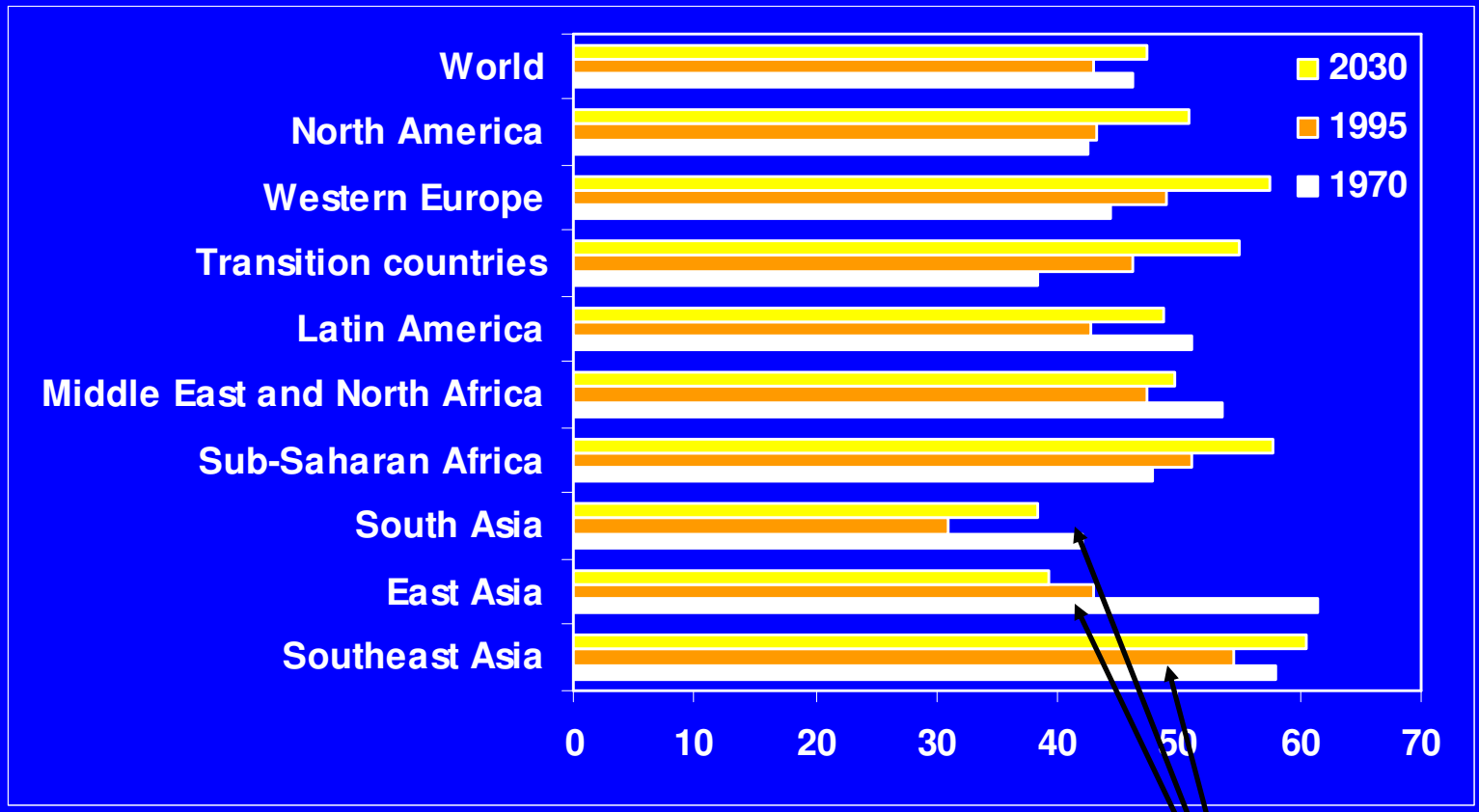
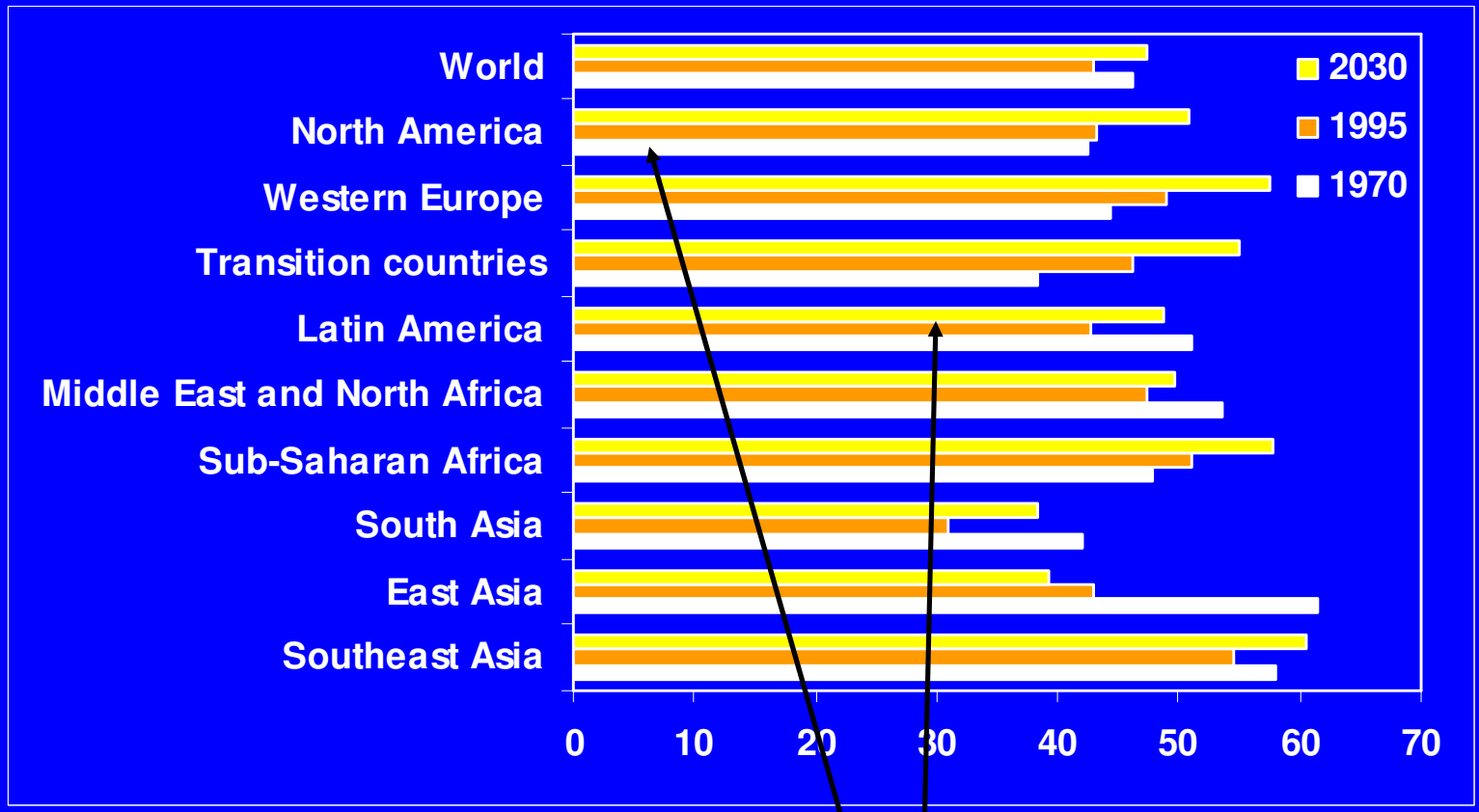


DIFFERENCES HAVE MANY CAUSES:

- Soil N depletion
- Climate/soils
- Productivity
- Management
- Over-fertilization
- Mix of crops (wetland rice)
- Legumes
- Underestimation of N in harvest

Intensive systems:
Overall system N recovery in % of inputs



DIFFERENCES HAVE MANY CAUSES:

Soil N depletion
Climate/soils
Productivity
Management

Over-fertilization
Wetland rice
Legumes
Underestimation of N in harvest

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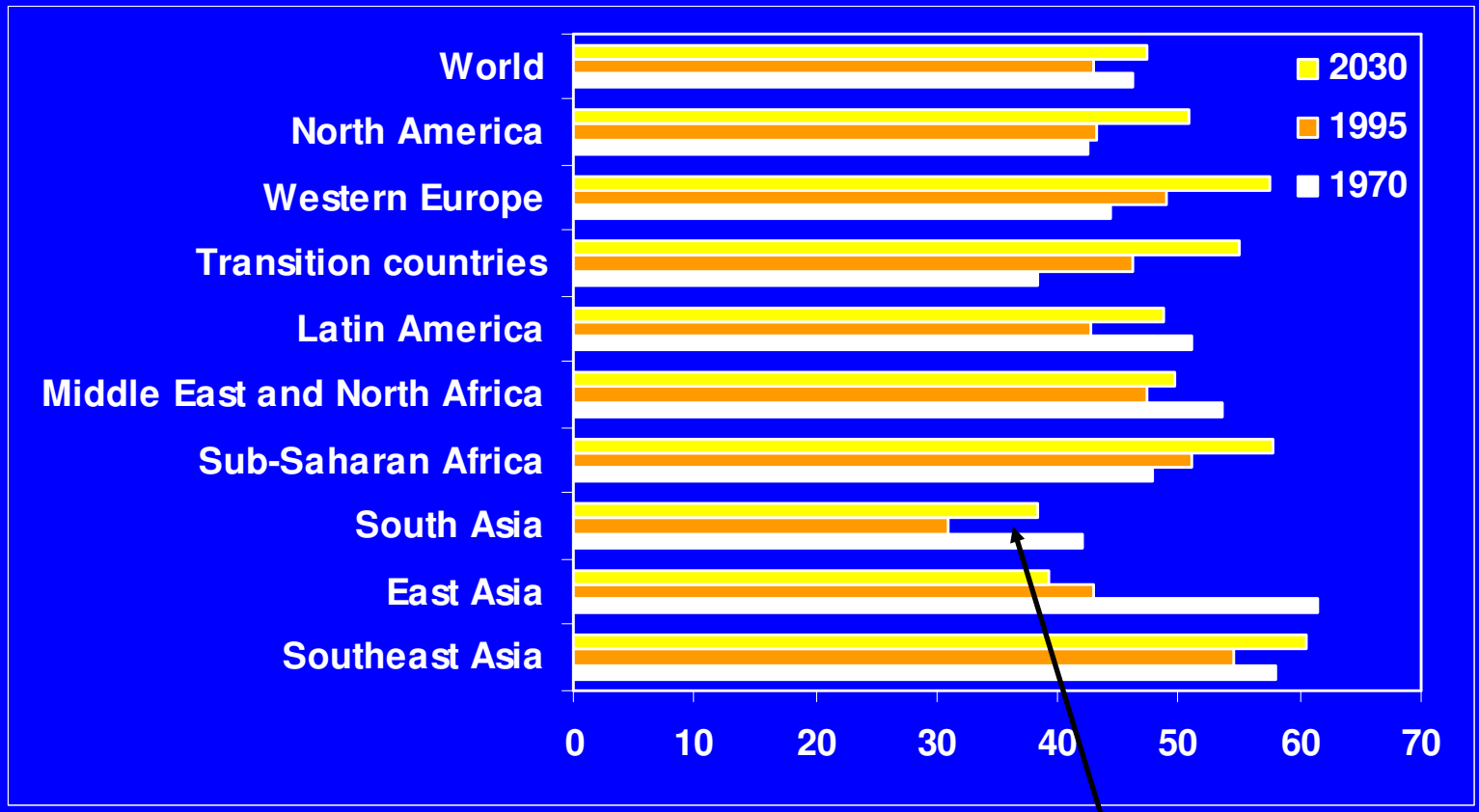

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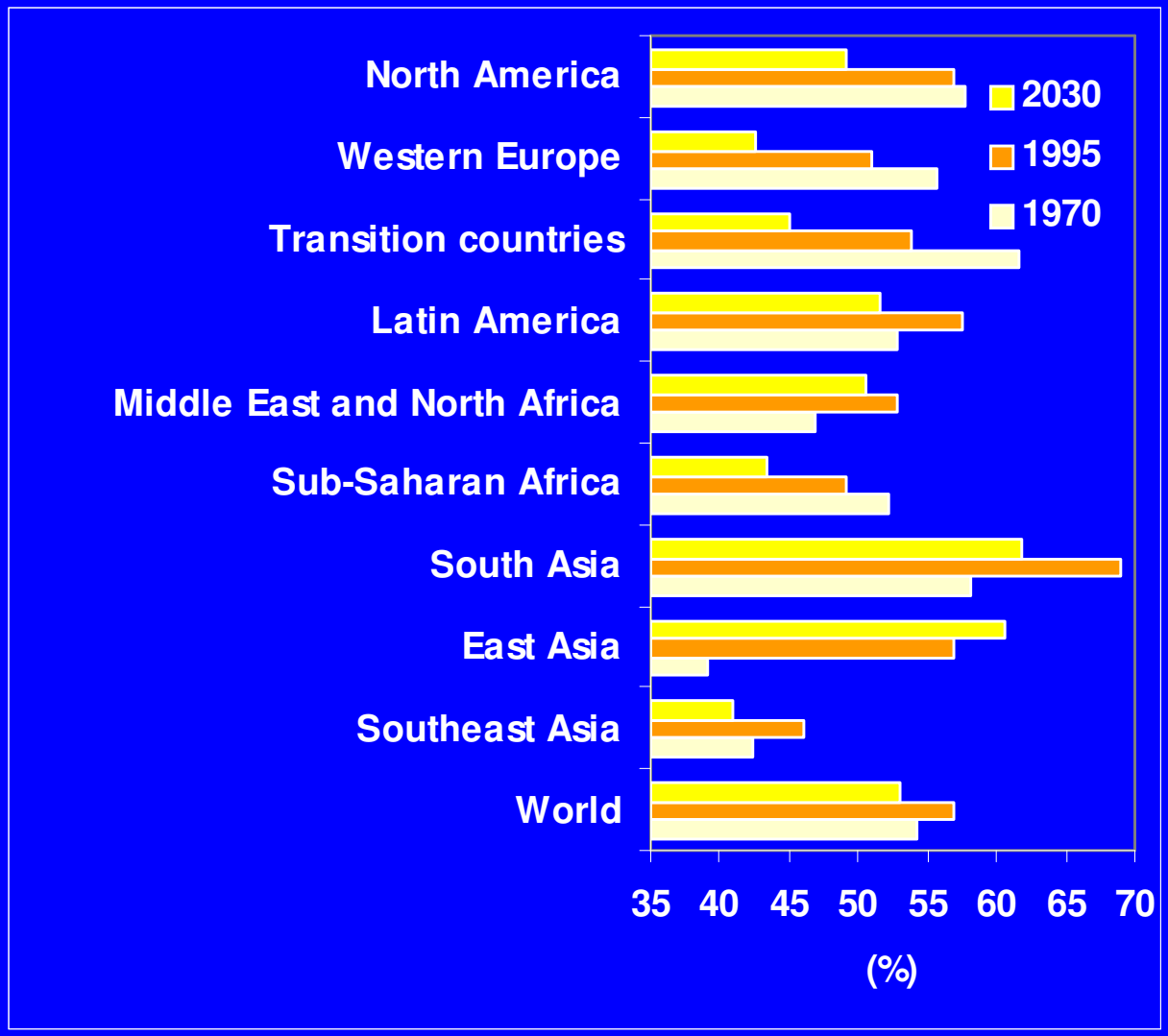
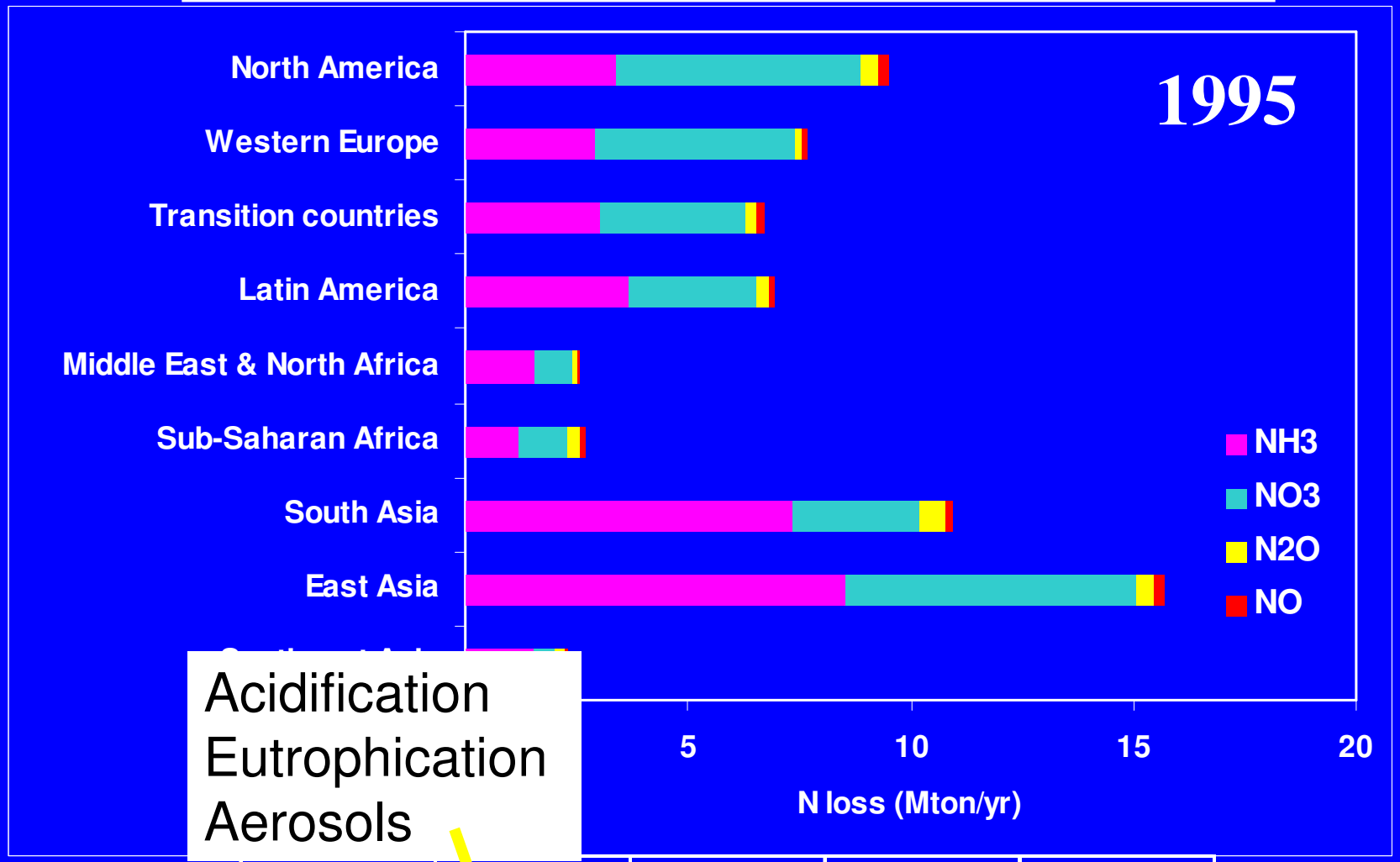
Intensive systems: N loss in % of inputs



N loss is complement of system N recovery

Intensive systems: Total reactive N loss

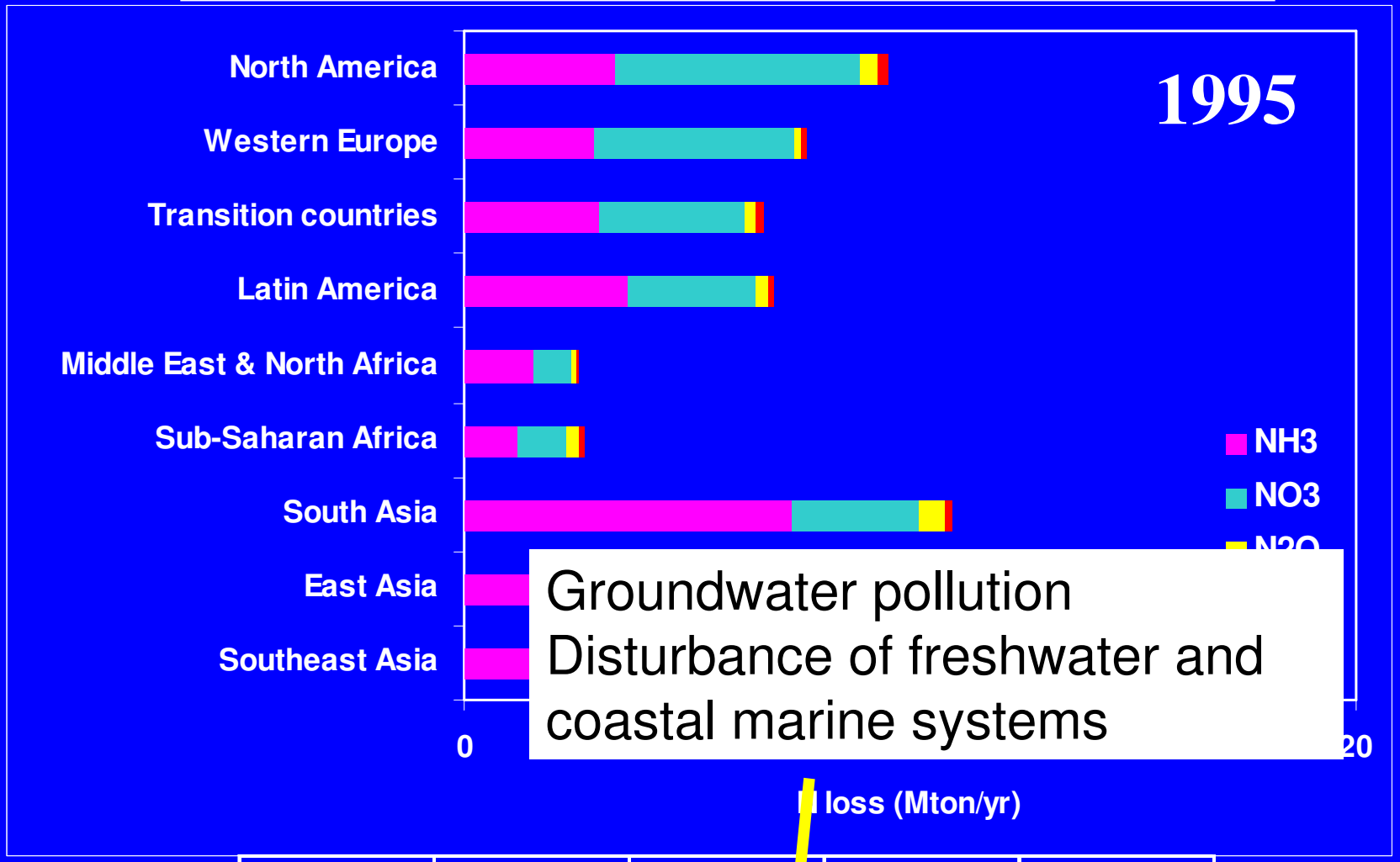


Acidification
Eutrophication
Aerosols

World

	NH3	NO3	N2O	NO
1970	**18.1**	**18.2**	**2.0**	**1.1**
1995	**34.2**	**28.5**	**2.7**	**1.5**
2030	**44.0**	**35.3**	**3.5**	**2.0**

Intensive systems: Total reactive N loss



Groundwater pollution
Disturbance of freshwater and coastal marine systems

World

	NH3	NO3	N2O	NO
1970	**18.1**	**18.2**	**2.0**	**1.1**
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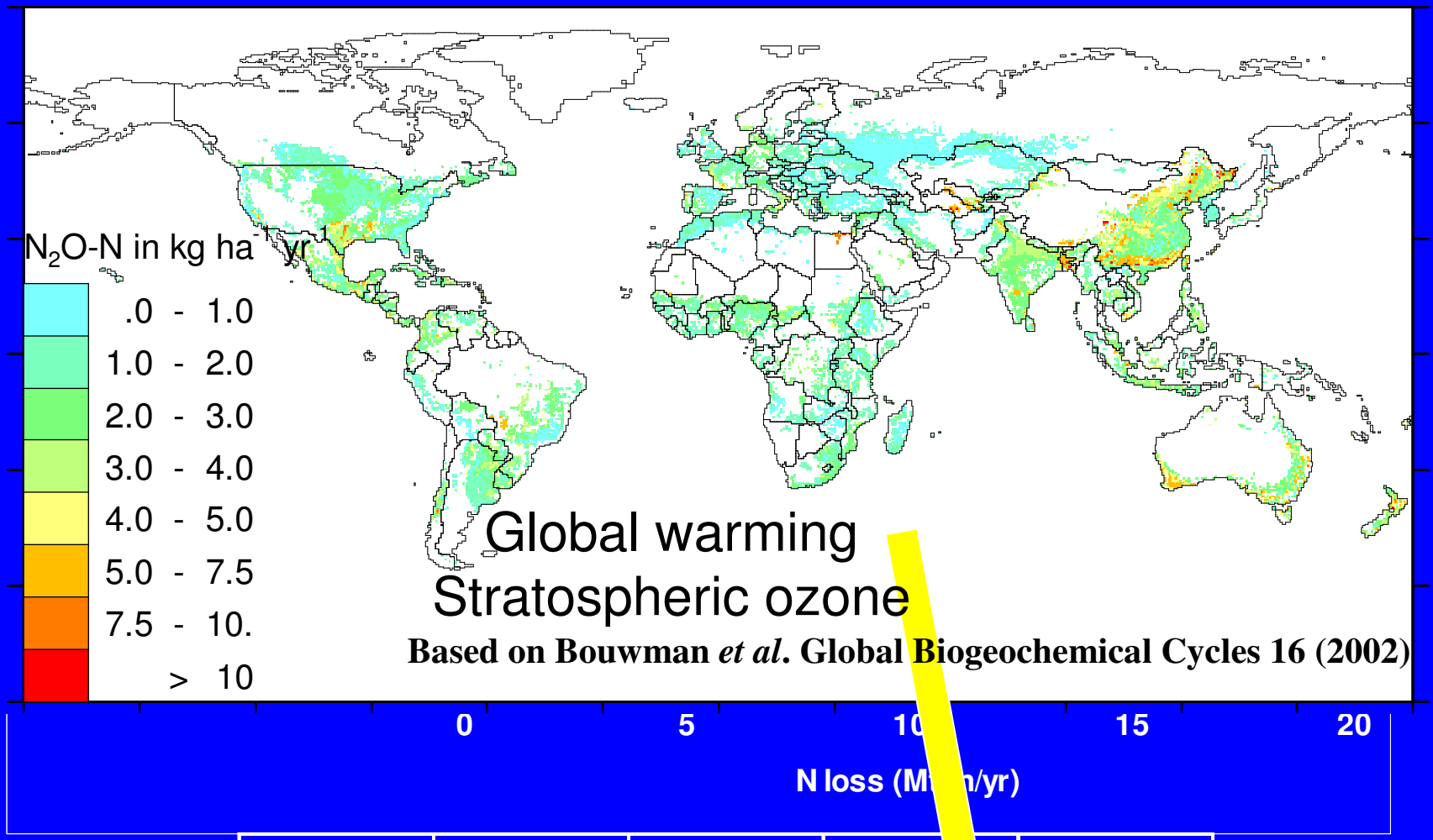
Intensive systems: Total reactive N loss



World

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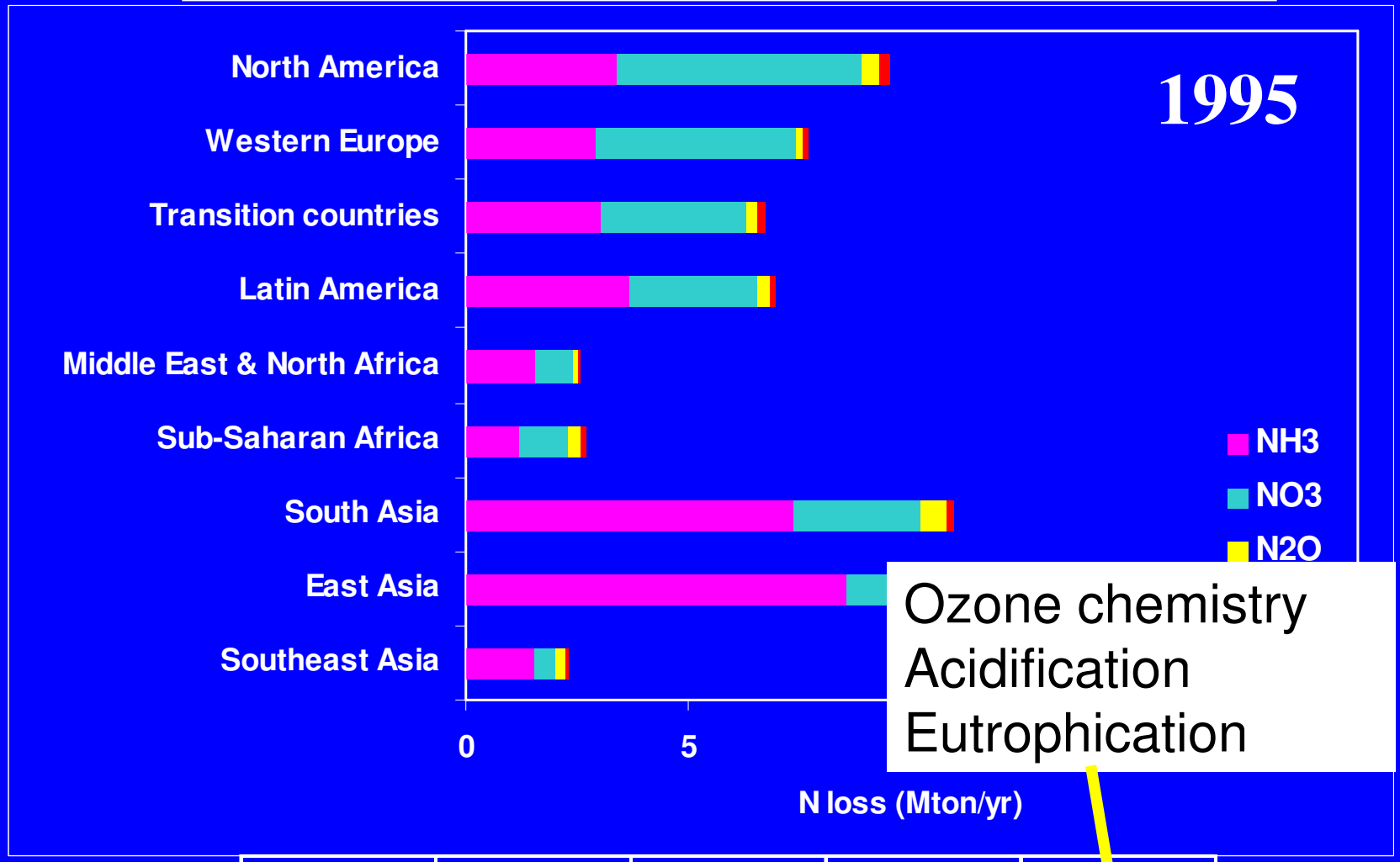
Intensive systems: Total reactive N loss



Ozone chemistry
Acidification
Eutrophication

World

	NH3	NO3	N2O	NO
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1995	**34.2**	**28.5**	**2.7**	**1.5**
2030	**44.0**	**35.3**	**3.5**	**2.0**

Concluding remarks

- **Considerable improvement of N recovery is possible**
- **But, differences in reactive N loss and system N recovery reflect a host of factors:**

-Agro-ecological resources (soils, climate)
-Management
-Mix of crops (wetland rice, legumes)

- **So, recovery and its improvement can not be the same everywhere**
- **Current N deficit systems may change into systems with surpluses**
- **Concentration of livestock and crop production**

Thank you !